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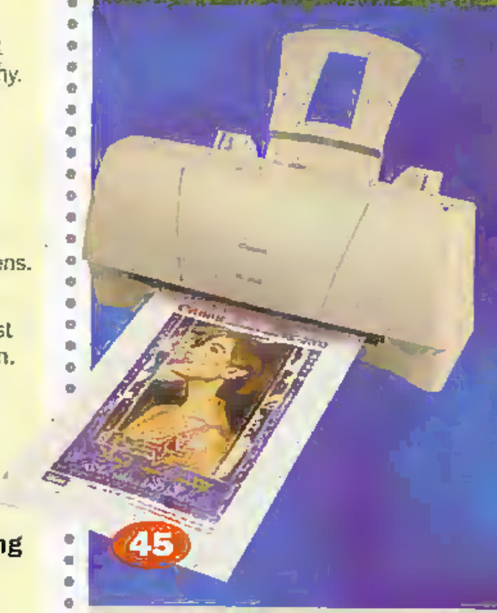
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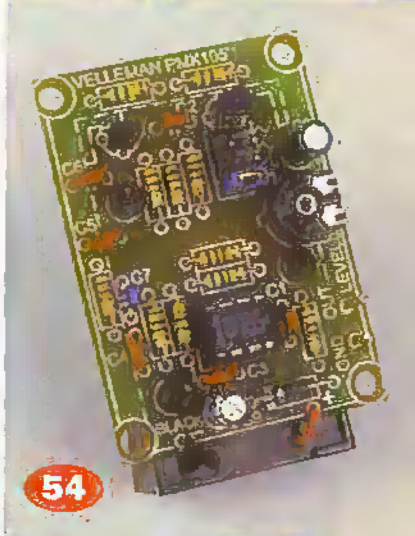
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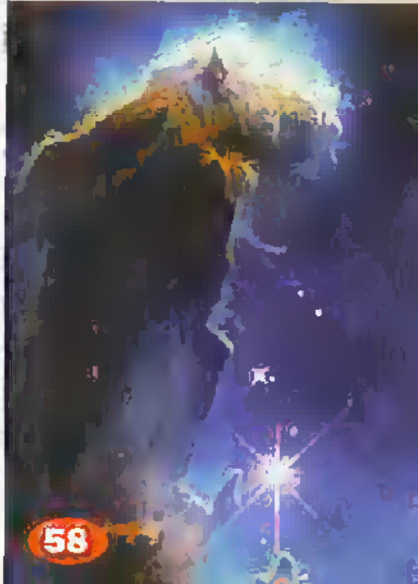
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ELECTRONICS and Beyond

Now that spring is here, and the weather, hopefully, is improving, we have a project for the outdoors - a metal detector. In part one, Gavin Cheeseman has a look at the theory and some possible designs. With part 2 of the project next month, there will be a short article from Gordan Bailey, who for 30 years has been searching the soil, and he gives an insight into the tricks of the trade along with details of the astonishing treasures he has uncovered.

For indoor leisure pursuits we have *Solar Flare* an electronic board game that can be very addictive, and indeed makes a pleasant change from the computer screen!

Whether we like it or not, the digital revolution is continuing at an unstoppable rate, so this month we have two articles on the very latest technologies - digital video/digital VHS, and the digital loudspeaker from 1... Ltd. of Cambridge. This latter development could well revolutionise the way we listen to music, and it is good to see a British company leading the field. Stephen Waddington paid them a visit to hear for himself and check on developments.

For readers who like some thought provoking reading, then Douglas Clarkson delves into the universe, particle physics, and life with his article *Towards A Theory of Everything*.

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Towards a Theory of Everything
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DV & DVHS Video Systems

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NEWS REPORT

NEC Shows Flat Panel Microdesktop

NEC's new desktop computer is a concept that features a revolutionary form factor and a combination of technologies unlike that found in any other desktop personal computer. The personal computer, code-named 'Millennium', integrates desktop, mobile and future technologies, including a built-in flat panel display, is a self-contained system with a footprint that measures 10.5in. wide by 7.7in. deep by 2.0in. high.

For further details, check: <www.nec.co.uk>.

Contact: NEC,
Tel: (0181) 993 8111

All-Star Signs To Playstation

Mo Vaughn, the All-Star first baseman of the Anaheim Angels, has signed an exclusive deal for MLB 2000 - the latest version of the popular baseball videogame for the PlayStation game console, set to be available in stores at the end of March 1999.

For further details, check: <www.playstation.co.uk>.

Contact: Sony,
Tel: (0990) 111 999

Intel Launches Pentium III Processor

Intel launched the Pentium III processor at the end of February. They claim it is the first microprocessor designed to power a new Internet experience filled with rich audio, video, animations and 3D that make information come alive. The Pentium III processor is available immediately at 450 and 500MHz, while the 550MHz version will be available in second quarter 1999.

The Pentium III processor at 500MHz is 93 percent faster than the Pentium II processor at 450MHz on CPU intensive 3D calculations, as shown by Ziff-Davis' 3D WinBench 99 transform and lighting test. Using Future Reality's Multimedia Mark multimedia performance benchmark, the Pentium III processor at 500MHz is 42 percent faster than the 450MHz Pentium II processor.

The new processor also offers a new selectable processor serial number feature that, when enabled, works in conjunction with security solutions to provide for more secure internet transactions. Corporate IT managers will be able to use the processor serial number feature to enhance asset management, making it easier to track PCs and applications on the network.

For further details, check: <www.intel.com/procs/perf>.

Contact: Intel,
Tel: (01793) 403000.

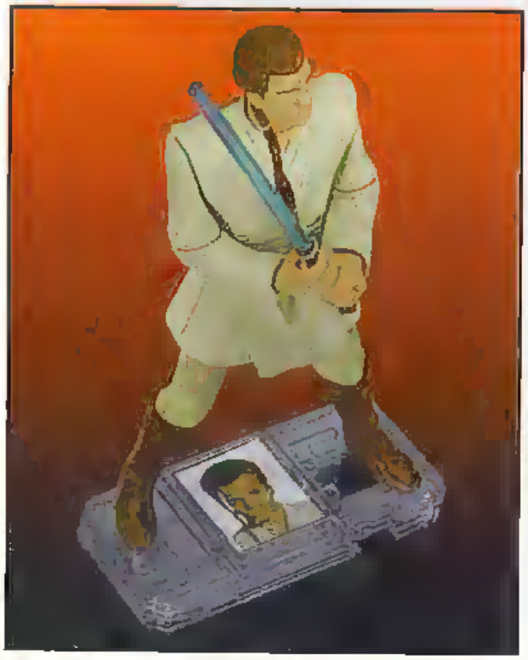
Technology for Star Wars

A new toy technology from Hasbro that brings a whole new type of play to the action figure toy category through its Star Wars basic action figures. The technology, called Communication Output Memory Module (COMMTech), is a patented microchip system that enables Hasbro's new action figures from Star Wars: Episode I to speak and re-create key scenes from the movie.

The new toys, due at retail in May to coincide with the film's release, pair the basic, four-inch Star Wars action figures from the new movie with digital audio COMMTech chips. To play, the child stands each figure on its COMMTech chip base, then scans the chip across a COMMTech Reader unit. The figures then speak with key character movie dialogue and many of them can respond to each other as they do in the movie.

For further details, check: <www.hasbro.com>.

Contact: Hasbro Interactive, Tel: +1 410 568 2377.



NEWS BYTES

Sony and MGI In Digital Promotion

MGI PhotoSuite, is to be included with Sony's Mavica MVC-FD81 and MVC-FD91 digital cameras, in a promotion that will run throughout 1999. Customers will receive a free Starters Edition copy of MGI PhotoSuite when they purchase either camera from Dixons stores.

For further details, check: <www.mgisoft.com>.

Contact: MGI,
Tel: (0171) 365 0034.

IT People Want To Be Treated Normally

People working in the computer industry would like IT issues to have more of an 'entertainment factor', according to research conducted by Britannia Software.

Britannia spoke to one hundred IT professionals as part of research into customer communication. Eighty percent of those questioned believed there was too much jargon associated with IT, which was a 'turn-off' both for those already in the profession and those thinking of joining.

Sixty-two percent of those questioned thought there was a lack of space and attention given to IT in the mainstream media, with few being able to mention existing technology radio/TV slots. Others thought there was ignorance of industry issues, with coverage on important topics such as Y2K often being 'alarmist' rather than informative.

For further details, check: <www.britannia-software.com>.

**Contact: Britannia Software,
Tel: (0181) 694 9494.**

Welsh 2m Radio Amateur Mast to Close

The two-metre radio amateur repeater GB3AR, which covers the north-west coast of Wales, is to close down at its present site towards the end of March. The reason is a sharp increase in the rental for use of the site which is owned by NTL. Whilst regretting this development, the Arfon Repeater Group is remaining positive and is actively looking for other sites. Further information can be obtained from the repeater keeper, Brian Davies, GW4KAZ.

For further details, check: <www.rsgb.org>.

Contact: RSGB,
Tel: (01707) 659015.

NEWS BYTES

I/O Alliance Is Out

The I/O alliance, including IBM, 3Com, Hewlett-Packard, Adaptec, and Compaq has announced new partnerships, a timeline, and details of the Future I/O specification, designed to increase by sixteen times the current speed of data transmission between databases, networks printers, and other devices that connect to a computer.

For further details, check: `<www.ibm.com>`.

Contact: IBM, Tel: (0990) 426426.

Digital Watermark Standard

The so called Galaxy Group of consumer electronics companies - IBM, NEC, Hitachi, Pioneer and Sony - have agreed on a new digital 'watermark' standard for preventing illegal copying of digital material. The watermark is an indelible binary code embedded in each frame of a digital recording so that a digital recording device will refuse to make a copy recognised as unauthorised.

For further details, check: `<www.ibm.com>`.

Contact: IBM, Tel: (0990) 426426.

Upgrade Available On Sony Vaio Modems

Portable communications specialist PPCP has announced GSM, ISDN and 10BaseT Ethernet upgrades for the 56K modems bundled with Sony's ultra-slim, lightweight Vaio notebook range. Once the modem is upgraded via a software patch, Vaio users can send and receive data and faxes from virtually any location, by high-speed analogue or digital land-line, or by GSM connection.

For further details, check: `<www.ppcp.co.uk>`.

Contact: PPCP, Tel: (0181) 893 2277.

Five Years' Data Salvaged In Five Days

Data recovery firm Ontrack has salvaged five years' worth of data for a firm of electrical contractors. The company recently lost irreplaceable financial records due to a faulty hard disk drive. Ontrack saved 100% of the data in five days.

Physical damage had made the files on the removable media cartridge unreadable. Ian Goddard Contractors sent the drive back to the manufacturers who recommended Ontrack. An experienced engineer was then able to open it up and examine it in the Ontrack clean room.

For further details, check: `<www.ontrack.co.uk>`.

Contact: Ontrack, Tel: (01372) 741999.

Matel Gets Intel Inside

Matel is set to launch a series of Intel powered toys ready for next Christmas. The Intel Play X3 Microscope and Intel Play Me2Cam, will be available from Mattel in Autumn. The products have been jointly designed and developed by a team of engineers and toy designers from the two companies.

With the Intel Play X3 Microscope, children can magnify and display microscopic objects on their PC screens and then play with the images in creative ways. The microscope uses digital video imaging technology to let kids view, enlarge and save images of bugs, plants and other everyday objects.

The Intel Play Me2Cam creates a whole new system of play where children see themselves on the computer screen and use their own bodies to navigate in a virtual world. The Me2Cam system comes with a digital video camera and CD-ROM software.

Meanwhile Purple Moon, the US start-up that attempted to pioneer computer games aimed at girls, has closed its doors. The company cited overwhelming competition from major toymakers like Mattel and Hasbro, which were able to tie their computer game offerings to popular toys such as Barbie and My Little Pony.

For further details, check: `<www.intel.com>`.

Contact: Intel, Tel: (01793) 403000.

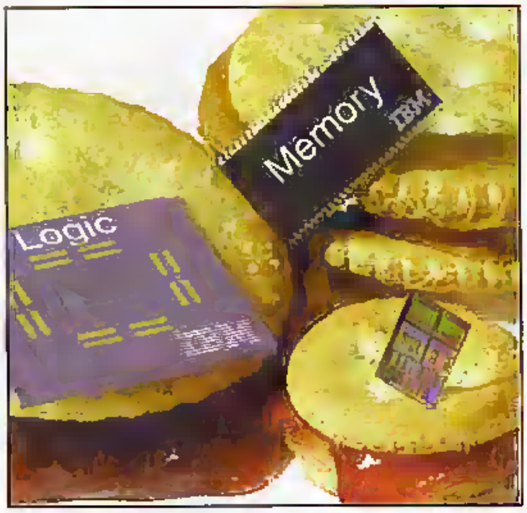
MIT Team Builds 40-Ton Magnet

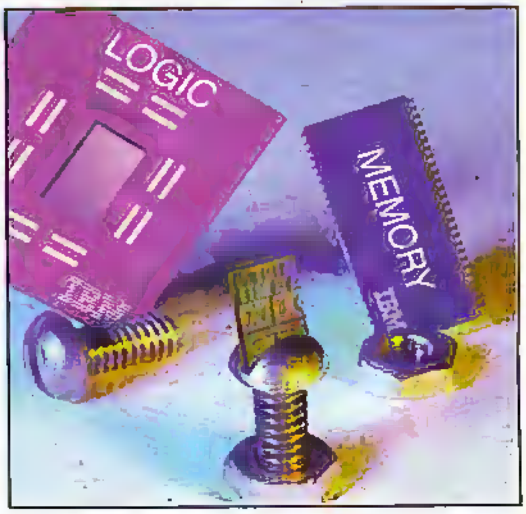
A US engineering team led by MIT has completed a 40-ton magnet that, when combined with a similar magnet in Japan, will serve as a test bed for the researchers' ultimate goal: a magnet weighing 1,300 tons that will be key to an international experiment on nuclear fusion.

Some of the technologies behind the US magnet could also have other applications. For example, it employs novel superconducting cables wound into a coil that could be adapted for energy storage or to stabilise disturbances on a power grid.

For further details, check: `<web.mit.edu>`.

Contact: MIT, Tel: +1 617 253 1000.





Shrink To Fit

IBM has found a way to efficiently place both logic and memory circuits on a single piece of silicon enabling complete electronic systems to be built on a single silicon chip.

Logic circuits process information, while memory circuits store information; the two are used in tandem to add intelligence to electronic products. Until now, the two functions have normally been provided on separate chips, adding complexity and cost.

IBM claims that this could significantly enhance the performance of many electronic products, from personal computers to cell phones to video games, while reducing the number of chips inside, making products smaller and less expensive.

With IBM's technology, twenty-four million 'gates', or circuits - equal to as much as eight times the processing and two to four times the memory found on today's typical PC - can be packed on a single chip.

According to IBM, this removes a major hurdle in the electronics miniaturisation race, clearing the path to eventual system-on-a-chip products and a new wave of pervasive computing devices. IBM plans to start designing custom chips with this capability in April of this year.

For further details, check: `<www.ibm.com>`.

Contact: IBM, Tel: (0990) 426426.

3Com Launches New Pilots

3Com has added two new products to its portfolio of handheld computing products: the Palm V and the Palm IIIx connected organisers.

The Palm V organiser has an ultra-thin industrial design, convenient new features - such as a rechargeable battery so the device maintains a continuous power supply - and a full line of matching accessories.

The Palm IIIx organiser, a new addition to the Palm III product line, is designed for consumers and corporate users who require increased storage capacity for data and applications. The Palm IIIx product offers twice the memory, enhanced expandability and improved durability over the original Palm III product.

Both models feature new advanced liquid crystal display screens with improved contrast and clarity for easier viewing. The Palm V and Palm IIIx organisers are available immediately, however UK pricing is yet to be announced.

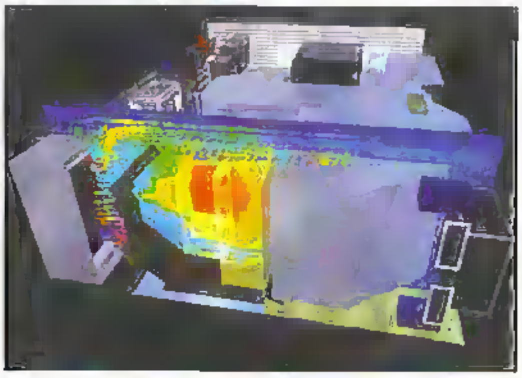
For further details, check: <www.3com.com>.
Contact: 3Com, Tel: (0118) 927 8200.

Heat Sensitive Projector Cuts Noise

Philips Creative Display Solutions has used thermal management software from Flomerics to create a virtually silent multimedia projector. Projectors of this type of typically noisy due to internal cooling fans.

Using Flotherm, a thermal management application from Flomerics, to determine the air flow, heat flow and temperatures within the projector, Philips engineers were able optimise the location of the critical components and create a system with the coolest possible layout.

The projection lamp, the component dissipating the most heat is placed at the end of the air-flow chain, so that the hottest air was blown straight out of the unit and not over the PCBs. A microprocessor designed to continually read signals generated by the temperature and flow sensors was installed to control the speed of the cooling fans.



Thanks to this new layout, the fan noise, which can often be a major distraction to listeners is virtually undetectable – operating a just 33dB(A). This is a comparable to that of a human whispers and claims Philips four times lower than the noise level of its closest competitor.

For further details, check: <www.flomerics.com>.
Contact: Flomerics, Tel: (0181) 941 8370.

Young Ones Build Kits at RSGB Stand - Olympia

The Radio Society of Great Britain (RSGB) shared a stand with the Joint Radio Control Users Committee (JRCUC) in the Club Village at this year's International Model Show at Olympia this year. The JRCUC was formed to negotiate with the RA on behalf of radio control users to improve frequency allocations and standards here and in Europe.

With the help of Maplin Electronics and Peter Thomas at JAB Components, who provided the kits, youngsters were able to build simple projects and take them home afterwards. Video demonstrations of amateur radio were running continuously on the stand.

Volunteeers from the Milton Keynes ARC and RSGB, showed young people from seven to 17 years old how to solder and construct a simple, working, kit. There were so many youngsters wanting to join in that two workstations were set up on the stand on several occasions.

Nexus, the organisers of the event, thought the stand was so good that they awarded it 'The Best Non-Engineering Stand' at the Show! So, hopefully, the exercise can be repeated next year.

Time will tell whether the enthusiasm ignited in these youngsters will culminate in them gaining an amateur radio licence, but there are a great deal more people - young and old - who now know that amateur radio is still very much alive and kicking!

Eye Tracking Hardware

Vision Control Systems has launched an off the shelf eye-tracker system. The application integrates a miniature camera, holographic optics and signal processing to track the user's precise point of observation.

For further details, check: <www.visioncs.com>.
Contact Vision Control Systems, Tel: (0161) 624 0281.

Supercomputer Develops Safer Cars

Ford is using a Silicon Graphic's Cray T90 supercomputer to achieve a record level of sustained performance on production jobs - more than one gigaflop, equivalent to one billion floating point calculations per second - when running RADIOSS, an advanced automobile crash analysis application.

Ford, which recently ordered a third Cray T90 system because of the impressive performance, also uses a 64-processor Silicon Graphics Origin2000 supercomputer in the crash work.

For further details, check: <www.sgi.com>.
Contact: Silicon Graphics, Tel: (0118) 925 7500.

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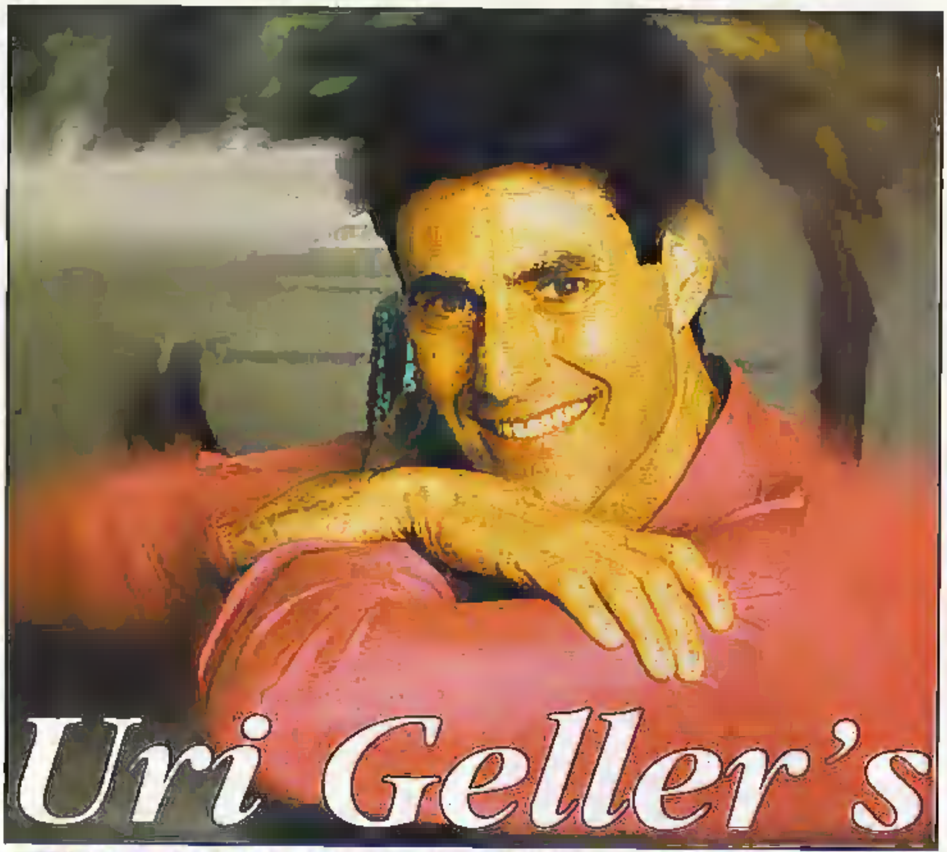


Uri Geller's EXTENDED REALITY

Mind Transplants?

Ever since Dr Christiaan Barnard performed the world's first human heart transplant in 1967, hundreds of people have been given a few extra years of life thanks to those whose internal organs have been made available after their deaths for the benefit of others. Before that historic operation, it was generally thought that transplants would not work because the recipient's body would not be able to assimilate them, since human bodies are programmed to reject invasions of any kind.

Now it seems that when an organ is transplanted, something else comes with it. You may have seen the item in the recent BBC series Mysteries with Carol Vorderman in which a woman named Julie Shambra described how her personality seemed to have changed when she was given a new kidney. "So many things changed so drastically," as her mother put it. For example, she suddenly showed a great enthusiasm for boxing and football, although she had not had the slightest interest in either before her operation. She became generally more extravert and began to act more like a man than a woman on occasions.

Although doctors usually do not encourage transplant patients to locate the families of their donors, Julie Shambra managed to find the mother of the young black man whose kidney she now had. The two women developed a close bond, and the mother admitted that her son had indeed been a fanatical sports fan.

I have just come across an even more remarkable case dating from 1988, in which a 47-year-old woman named Claire Sylvia, a drama teacher from Boston, Massachusetts, was given a new heart and lung. When she had recovered, a press conference was held in the hospital and a reporter asked her if there was anything she would particularly like to have.

"To tell you the truth," Claire replied, "right now I'd die for a beer". It was a strange thing for a woman who had just nearly died to say, especially since she did not like beer and never had liked it. She was as surprised as anybody else by her remark, and wondered why she had said it.

A few weeks later, when she was able to drive, she made a bee-line for the local Kentucky Fried Chicken shop. Again, she asked herself what she was doing, because she had never liked the stuff. She noticed several other changes in her personality and, on an impulse, set out to discover whose heart and lung she now had. All they would tell her at the hospital was that the donor has been an 18-year-old male who had been killed in a motorcycle accident somewhere in Maine. (It was not known if he liked beer and fried chicken, but this seemed quite likely.)

Now the story gets even stranger. One night, she had a very unusual dream in which she met a young man who, she was sure, was the donor of her new heart and lung. At the end of the dream, they kissed and Claire felt as if his whole body had merged with her own. His name, or rather his initials, were TL.

She happened to describe the dream to a friend, whereupon the friend had a dream in which he was looking at an item in a local newspaper about a young man who had died in a motor-cycle accident.

This prompted Claire to go to the library and search through the Maine newspapers, and sure enough she did find such an item. To her astonishment, the name of the victim was Tim Lanirande - TL! She located his family and was given some information about Tim, including the fact that at the time of the accident he had actually been carrying a box of fried chicken with him, and he did like beer. Claire was able to visit the scene of the accident and also to visit Tim's grave, and became convinced that she and he were permanently linked, although she insisted that she had only picked up some of his likes and dislikes and had not been entirely taken over by him. All the same, Tim's sister did mention that Claire somehow reminded her of her brother.

As for Claire herself, she believed that knowing her donor's identity was vitally important to her in helping her body to accept a foreign organ, and to go on living a good deal longer than the average recipient of a heart and lung.

Not everybody agrees with her. The head of the transplant unit at the hospital where she had her operation would have none of it. He was strongly opposed to the idea of letting recipients find out who their donors were, and rejected the notion of 'cellular memory' out of hand. "To the best of anyone's knowledge," he declared, "it does not exist." Her surgeon would not even discuss the matter.

Cases like those of Claire and Julie are rare, and several transplant recipients who have been questioned have not mentioned feeling any different, personality-wise, since their operations. However, we only need one good case to establish the possibility that some of our personalities may be distributed around the body, and the cases of both these two women seem to have been well witnessed by independent observers.

Obviously we need more evidence - and it may not be easy to get it - before we leap to any conclusions. Yet I see that the phrase 'trait transfer' has already been used by some enterprising researchers in Israel (I am making further inquiries there) and it may indeed be that when somebody is given a piece of somebody else's body, they are also given a piece of their mind.

Uri Geller's novel Ella is published by Headline Feature at £5.99, and his Little Book Of MindPower by Robson Books at £2.50, and Jonathon Margolis' Uri Geller Magician or Mystic? by Orion Books at £17.99.

Visit him at `www.tcom.co.uk/hpnet/` and e-mail him at `urigeller@compuserve.com`

Uri Geller

A Truly DIGITAL SOLUTION

Almost every element in the audio chain is now digital. Except perhaps the most important – the loudspeaker. But that could be about to change. Here Stephen Waddington looks at a new speaker technology that could see the first truly digital audio systems within the next two years.

A Cambridge based company claims to have invented the world's digital loudspeaker (DLS) technology and has announced plans to commercialise the technology within the next two years. That company, curiously named 1... Limited is now set to license its technology to development partners around the world.

The 1... Limited DLS is based on a fundamentally new design approach. Based on a flat panel matrix of novel piezo-electric long-throw transducers, the speakers are driven via digital, rather than conventional analogue signals. In this way 1... Limited claims that it can control the direction and audio levels emitted from the DLS more accurately than with any other existing audio technology - delivering significantly advanced sound quality.

What's in a Name

1... Limited is a three-year old company, created to research and develop digital loudspeaker technology. Based in Cambridge, the company is headed by Dr Tony Hooley, a Cavendish Laboratory, Cambridge University physics PhD and a one-time IBM Research Fellow at the Institute of Astronomy, Cambridge.

Photo 1. Conventional moving coil loudspeakers are more than 70 years old.

1... Limited currently consists of three staff, with a further six academic researchers based with the universities of Cambridge, Birmingham and Paris, working under contract to the company under the leadership of Dr Hooley. The company has more than 15 patent applications in the area of loudspeaker technology. These applications relate to both the electronic and mechanical properties of the DLS.

Weak Link

According to 1... Limited conventional loudspeakers are by far the weakest link in the chain between recording live sound and reproducing it. Modern microphones have near perfect performance.

Low noise electronics and digital recording and playback systems (such as DAT, Compact Disc and DVD), together with the latest power amplifier electronics can produce nearly ideal performance, with distortion levels in the best equipment well below the 0.005% level.

Unchanged Melody

By contrast, the very best conventional loudspeakers operate at about the 0.5% distortion level (100 times worse) and standard moderately priced hi-fi system loudspeakers often have worse than 1% distortion levels, particularly when operating at the higher power levels.

Feature	Benefit
All digital, allowing direct connection to digital sources, including CD, DVD and digital radio and TV	Better quality and simpler interface
Flat or other novel configurations	Many design and installation possibilities
Lighter in weight, less bulky	Less intrusive, easier to mount, and to move
Cannot be overdriven	Very robust and loud without risk of damage
Speakers identical	No pair matching problems
Single speaker covers entire audible frequency range	No woofers and tweeters, or analogue cross-over artefacts
Modular construction	Clip-on additional identical elements to improve quality further, or increase sound level
Mass production techniques will make core components very cheap	Potential low cost, but high quality and reliability
Consumes almost zero power when no sound being produced	Runs cool, could leave on permanently
Simultaneous multi-channel signals can be broadcast from central control unit to speakers in various rooms	Convenience and flexibility
No heavy signal-power cables required. Signals transmitted to speakers by radio	Can be wire-less connected to signal source No cabling problems
No analogue cross-over filters needed	Reduces system cost, improves quality
No Power Amplifier	Reduces system cost and power consumption and thus heat output
No D to A converter	Reduces system cost

Table 1. Features and Benefits of DLS Technology.

When you consider that most conventional loudspeakers as shown in Photo 1 are almost unchanged from the original moving coil speaker invented in the 1920s this is not too surprising, the principal improvements being mainly in materials: better magnets, better cone materials, and better suspension materials, with some contribution from better design practices.

Such analogue speakers generally require a fairly heavy and bulky cabinet that makes them essentially fixed items, especially when taken together with the heavy power-carrying loudspeaker cables connecting them to the power amplifier. These cables are heavy gauge because conventional speakers are inefficient, and convert only about 1% of their electrical input power into sound.

Thus a 1W acoustic output loudspeaker needs approximately 100W of electrical input power: hence speaker heavy cables. A further consequence of this inefficiency, is that these loudspeakers require high-power amplifiers to generate the 100W or so of input drive power, the vast majority of which is dissipated as heat within the loudspeaker. Such amplifiers also generate considerable heat, require bulky heat-sinks and power supplies, and add considerably to the cost of a hi-fi system.

Benefits of a Digital Loudspeaker

1... Limited's DLS technology tackles all of these problems. The company is aiming for an initial target of less than 0.1% distortion for the first production designs, with incremental improvements thereafter. Thus 1... Limited's first digital loudspeakers will be of better quality than can be bought at any price currently.

Because the DLS is entirely digital, its does not require a bulky analogue power amplifier, and so this component is entirely absent from the system. The heavy gauge speaker cables disappear too as there is no power amplifier for them to connect to - and the digital drive ensures that the DLS is impossible to damage by input signal overload.

As the DLS requires only digital input signals, these can be transmitted to the speakers by wireless or infra-red with no loss of quality using modern error correcting systems as required. Thus the DLSs have much more potential for being moved about the house, for example.

Because 1... Limited believes that it will be able to make much more efficient digital loudspeakers, a 1W output DLS might require only 2W to 10W (instead of 100W) of input power, and so operation from small rechargeable batteries becomes quite feasible. Thus no mains cable is required either.

1... Limited's transducers are much flatter than conventional high power loudspeakers allowing the possibility of smaller and lighter cabinets. A further novel technology the company is developing raises the possibility of completely eliminating the need for a loudspeaker enclosure, thus further reducing the weight and bulk of the DLS.

Photo 2. Tony Hooley with the Mark II version of the DLS.

Elegant Solution

The features and benefits of 1... Limited's DLS technology versus a traditional loudspeaker is shown in Table 1. All of these features taken together present the option of truly portable, wireless, hi-fi loudspeakers of top quality and high output level, but of light weight, low bulk and easy placement. A product concept for a digital loudspeaker incorporating these features is shown in Photo 2. They could be carried from room to room in the home, used in the bathroom or bedroom, on the patio, in the garden or by the pool. In commercial use, the benefits of ease of set-up and transportation, and overload-proof ruggedness, are unique.

DLS Technology

1... Limited's approach to loudspeaker design is radically different from conventional models. A schematic for the DLS is shown in Photo 3 The company replaces the one or two large analogue driver units found in most conventional loudspeakers with an array of very many, very small but identical digital driver units of novel design, each of which is driven separately by its own unique sequence of digital pulses. Photo 4 shows a prototype of such an arrangement using piezo-electric transducers found in fire alarms - sourced, incidentally, from Maplin Electronics.

A digital signal processing unit encodes input digital signals usually in binary code, into a very wide unary code which has uniquely useful properties for electro-acoustic conversion, among which are freedom from mostly-zeroes to mostly-ones code changes, and absence of high precision matching requirements in the transducers.

The signal processing also addresses other issues such as the ability to smoothly handle very loud and very soft signals (dynamic range), as well as tailoring the directional nature of the loudspeaker to suit the listening conditions, something virtually impossible to achieve with conventional loudspeakers.

The transducers themselves are very tiny (order of 10mm diameter) and yet taken together as an array are capable of

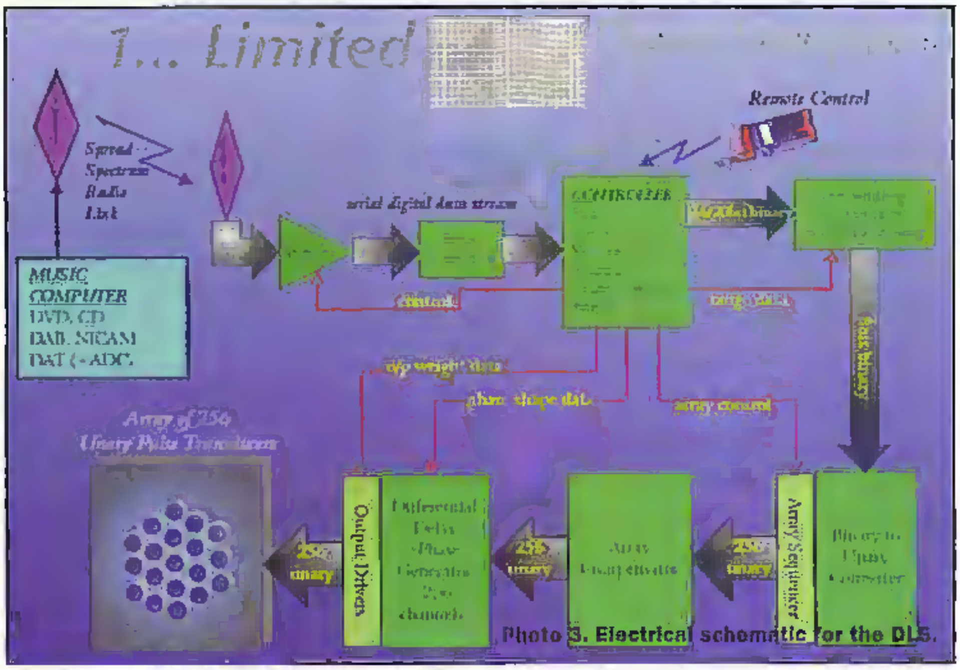


Photo 3. Electrical schematic for the DLS.

reproducing the full range of sounds normally covered only by combinations of large and small 'woofer' and 'tweeter' conventional speakers. This puts some severe demands on these transducers which accounts for their novel design. Side benefits of the design are much better efficiency and ease of housing.

How it Works

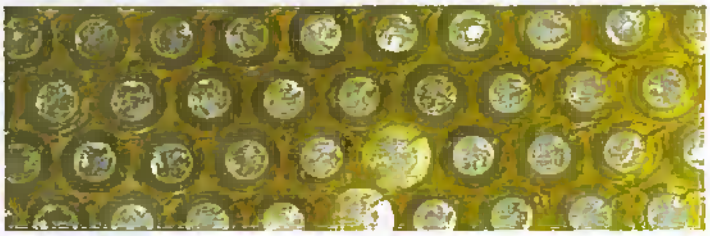
The operation of the DLS can be likened to that of the display on a lap-top computer. In such a display, the screen is made up of a large number of identical picture elements, or pixels. Each pixel can be turned on or off, independently. When looked at very closely, through a magnifying glass no displayed image will be seen - just a small collection of black or white squares. However, standing back from the display one sees the whole array of pixels and the displayed image is visible. Note that no single pixel on the screen represents all of the image, just a local portion of it.

In the same way, 1... Limited's signal processing electronics distributes components of the sound signal amongst the elements of the transducer array, driving each element with a unique signal. Listening to any one element you would not hear the sound that was to be reproduced, just some peculiar series of high-speed clicks. However, by standing back from the whole array so that your ears received signals from all of the elements, and adding all of their signals together in your ears, the sound would become apparent to you, just as the image on the display appeared, as described above.

Electronic Spring

In November 1998, 1... Limited, announced the basis of the electronic transducer that will form the 'pixel' elements within the

Photo 4. The DLS is constructed from an array of transducers. This early stage prototype uses piezo-electric transducers.



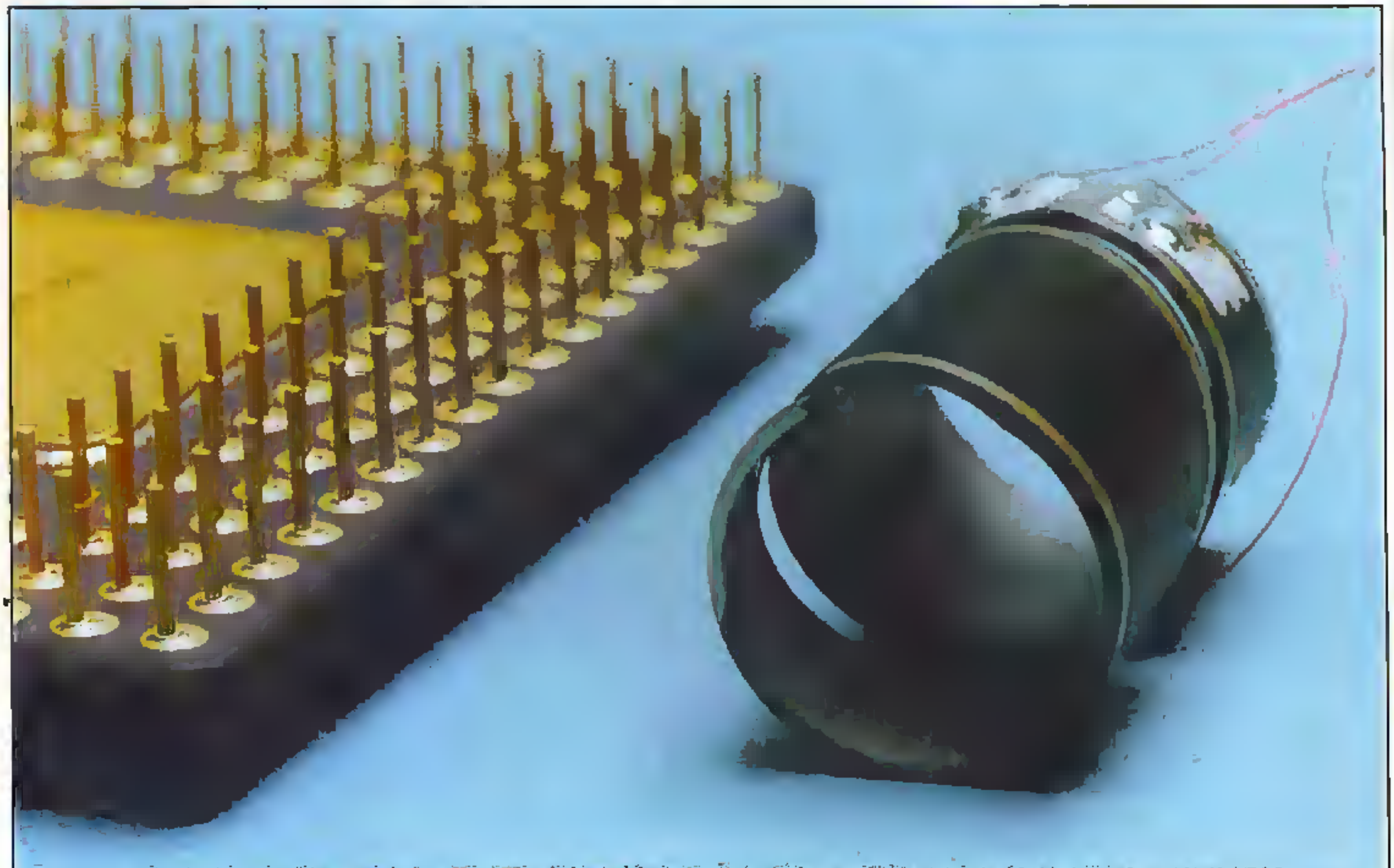


Photo 5. The electronic spring which contracts on the application of a voltage will form the basis of the transducer in the DLS.

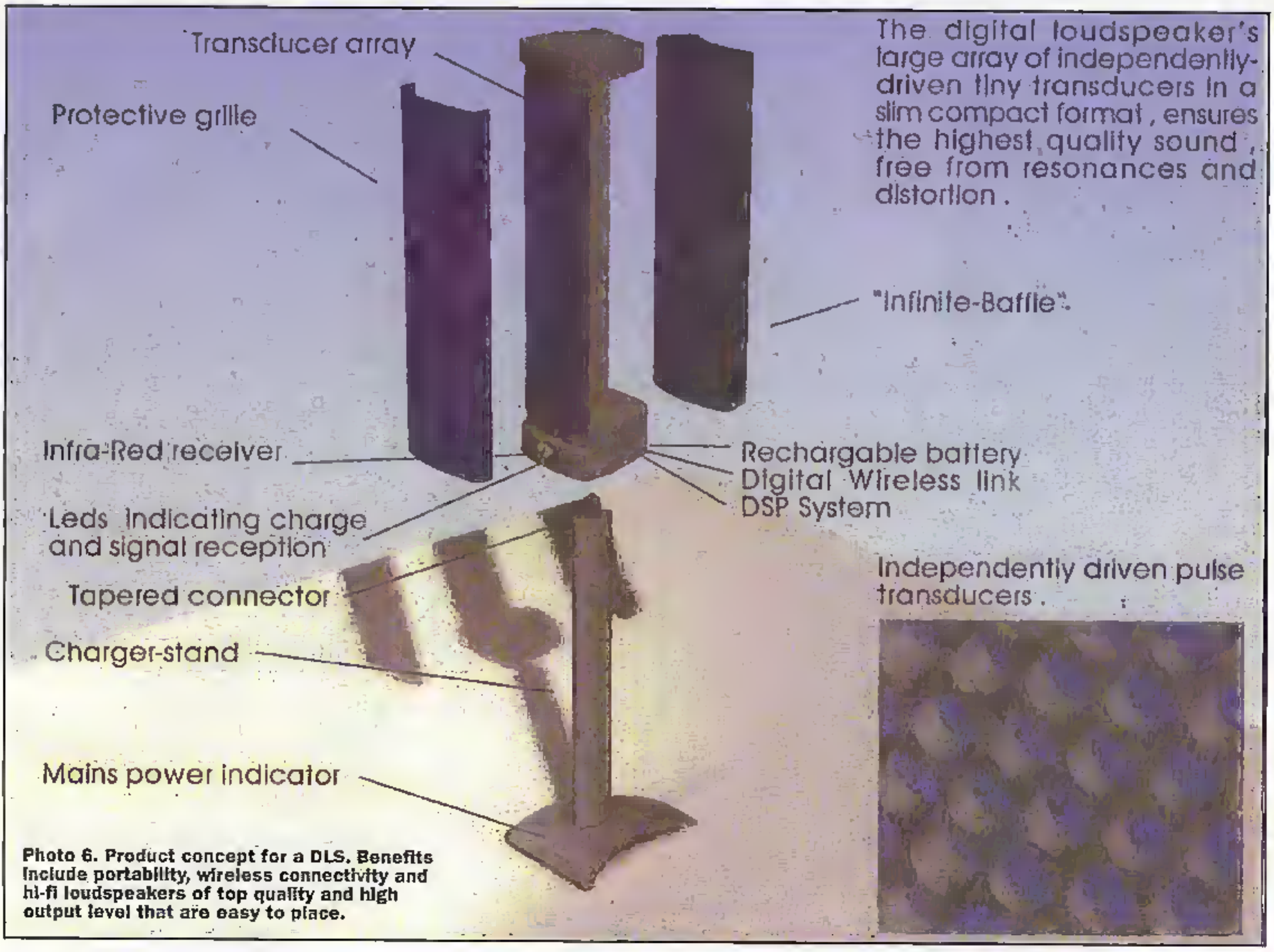

Transducer array
Protective grille
The digital loudspeaker's large array of independently-driven tiny transducers in a slim compact format, ensures the highest quality sound, free from resonances and distortion.
"Infinite-Baffle"
Infra-Red receiver
Rechargable battery
Digital Wireless link
DSP System
Leds indicating charge and signal reception
Tapered connector
Charger-stand
Independently driven pulse transducers.
Mains power indicator

Photo 6. Product concept for a DLS. Benefits include portability, wireless connectivity and hi-fi loudspeakers of top quality and high output level that are easy to place.

DLS. Working with its technology partner, the University of Birmingham Interdisciplinary Research Centre (IRC) for Materials, 1... Limited defied electronic and mechanical conventions to create an electronic spring, termed a helical PZT ceramic bender as shown in Photo 5.

The electronic spring device contracts and expands when a voltage is applied, providing the basis for a motor-like DLS transducer. Up until this point it was thought impossible to manufacture a multi-layer ceramic device in a helical arrangement.

But the electronic spring was made possible by the novel ceramics plastic-extrusion processing development spear-headed by Dr. David Pearce at Birmingham. The electronic spring will be used in 20mm lengths to form the basis of individual transducers that are set to make-up commercial versions of 1... Limited's digital loudspeaker (DLS).

Despite their minute size, the transducers themselves are capable of reproducing the full range of sounds normally covered only by combinations of large and small 'woofer' and 'tweeter' conventional speakers.

1... Limited's new transducer will consist of just three parts: the outer helical bender, an inner cylindrical piston made of extremely low density material, and a gas-filled bearing between the two which allows the piston to move freely along the axis of the helix with essentially zero friction.

In operation, the cone-like deformations of the helical bender squeeze the gas bearing radially, which in turn imparts axial forces to the piston which rolls on the bearing up and down the centre of the helix, up to 10mm in either direction.

Development of the unique bearing structure is now also making good progress and a demonstration bearing is expected within the next two months, after which an entire transducer assembly will be possible.

Future Plans

Having developed the DLS to an initial prototype stage as shown in Photo 6, 1... Limited is set to build on existing academic partnerships and forge new relationships with companies with proven expertise in traditional loudspeaker technology and leading-edge areas of technology such as piezo-electrics and electro-magnetics in a bid to commercialise its core technology.

In July 1997, the 1... Limited DLS project entered its second phase, partly funded by DTI SPUR Award. Phase I was a feasibility study to show that recognisable sound could be produced using an array of transducers emitting only acoustic pulses. In Phase II, 1... Limited is actively designing and investigating the novel transducer technologies necessary to build a commercial device as well as refining the necessary digital signal processing algorithms.

Another Cambridge Success?

But will the DLS succeed? Danny Chapchal boss of neighbouring CDT in Cambridge reckons 1... Limited has taken the right approach.

"1... Limited is in a very similar position to that of CDT two years ago, when I initially came on board. Like CDT, the company has developed a technology in the form of the digital loudspeaker, that has the potential to dislodge a more traditional solution, and thus impact world markets worth millions of dollars annually.

"Interestingly 1... Limited has recognised the needs to follow a business strategy of licensing and partnership in order to deliver the technology to market as early as possible. This is a new approach for Cambridge companies that have traditionally tried to go it alone. CDT and ARM are the exceptions to the rule.

"Two years ago I set in place a plan of commercial partnerships and licensing arrangement at CDT. By working with companies such as DuPont and Philips, Seiko-Epson, Hoechst, Uniax and IDT we have been able to progress the technology and reach markets far faster than we would have alone.

"From a technology stand point, CDT's LEP products and 1... Limited's digital loudspeakers have the potential to radically impact the consumer electronics industry. The similarities and potential synergies from both a business and technology perspective between CDT and 1... Limited are uncanny."

Royal International AIR TATTOO 1999

In Partnership with **BRITISH AEROSPACE**
RAF Fairford Gloucestershire, 24/25 July.

We have lift-off!

The Royal International Air Tattoo will send you into orbit with high-flying airshow entertainment. As well as a sensational eight-hour flying display performed by real-life Top Guns, there will be a full two miles of parked hardware, hot air balloons, the razzamatazz of military bands, stalls, exhibits, roadshows and much more besides. The magnificent 11 Frecce Tricolori will head the list of national aerobatics teams to say Happy 35th Birthday to the famous RAF Red Arrows.

In all, over 450 of the world's greatest aircraft will appear at the show - for Tattoo visitors, size does matter.

Spotlight on NATO

You've seen them on the news, you've read about them in the newspapers. Now the airborne might of NATO will roar into RAF Fairford for a mammoth 50th anniversary celebration. Highlighting aircraft from both sides of the Iron Curtain, the unfolding drama in the skies will evoke the tense decades of the Cold War, the fall of the Berlin Wall, and operations in Sarajevo. And the very latest aircraft - bristling with new technology - will demonstrate NATO's 'power for peace' into the 21st century. East will meet West in an horizon-wide finale, opened by the dare-devil Falcons Parachute Team of the Royal Air Force. Over 50 aircraft will line up on the taxi-way, canopies up, lights on, as hovering helicopters fly the national flags of NATO countries. Overhead Allied and former Eastern Bloc aircraft will fly past in a soaring demonstration of international friendship, led by the world famous Red Arrows.

The NATO 'Pit Stop' Challenge

This unique contest will see NATO engineers on red alert, racing against the clock and each other to equip aircraft for another sortie. The teams will work on aircraft deployed by one of their NATO partners, so you could be watching the RAF preparing a MiG-29 for combat. Look out for the 'Pit Stop' Challenge at the centre of the show - the finals will be run on Sunday 25 July.

See you in Fighter Country

The Guardians of the Sky come down to earth for Showcase N ATO, a living museum dedicated to the aircraft, work and history of the Alliance. In an airshow first, the vast ground-based display will lead you through Fighter Country, Strike Country, Airlift Country and other spectacular NATO themes to the elegant striped aircraft of 'Tiger Town'. Along the way you will have your chance to talk to international aircrew and take a look at some of their mean machines.

75 Years of The Royal Auxiliary Air Force

Formed by Lord Trenchard in 1924, the Auxiliary Air Force Squadrons went on to fly with great distinction during World War II - an esprit de corps which persuaded King George

ADVERTISEMENT

Royal Air Force Red Arrows Aerobatic Display Team.

VI to confer the Royal prefix on the service.

Today's Royal Auxiliary Air Force will celebrate its 75th anniversary by inviting Air Force Reserves from around the world to join in an hour long flying pageant. But for many, the star of the show will be a Battle of Britain Memorial Flight Spitfire which the AAF flew to glory more than 50 years ago.

Strike up the Band

Royal Air Force and NATO musicians will be in foot-stomping form as they play a free two-hour sunset concert. What's more, the stirring music will launch over 40 multi-coloured hot air balloons into the evening sky above RAF Fairford. The latest big screen technology will give you close-ups of the ascent and of individual performers on stage. In fact, all the day's action will be captured on big screens - including pilots preparing to display at the Tattoo.

Timetable

The gates to RAF Fairford open at 6.30am on Saturday and Sunday. The flying display starts at 10.00am, but in the meantime ground entertainment will be in full swing as strolling players, jugglers and jazz bands set the scene for the Summer's most exciting day out.

Enthusiast Day - Friday 23 July

For the first time The Royal International Air Tattoo will open its gates to the public on Friday - giving aviation enthusiasts a sneak preview of the parked aircraft on show at the world's biggest military air-fest. It will also be a big day for keen photographers who naturally want clear shots of all this exotic hardware before the crowds arrive for the weekend.

Only 5,000 preview tickets are available (adults £19.95 in advance - £25 on the day. Children 15 and under free). Call 01285 713456 for information and bookings.

Tattoo Hotline 0891 122999

Just a phone call away - info on aircraft, facilities, attractions and RIAT 99 ticket prices. With the press of a button you can also buy your advance airshow tickets on the Hotline, saving over £5. Adult advance tickets £19.95 (£25 on the day). Children 15 and under free.

(Calls to 0891 numbers cost 50p per minute, of which 15p per minute is donated to The RAF Benevolent Fund Enterprises, PO Box 1940, Fairford, Glos GL7 4NA). Tickets purchased direct from RAFBFE at RAF Fairford automatically incur a £2.00 per order administration charge).

Advance tickets also available from branches of Waitrose and Victoria Wine. For discounted group bookings (25 tickets or more) plus RIAT 99 enquiries, phone 01285 713456.

Website : `www.airtattoo.com` - regularly updated with the latest news from The Royal International Air Tattoo 1999.

SPOT-THE-DIFFERENCE DRAW!

WE HAVE 15 PAIRS OF ADULT TICKETS FOR THIS SPECTACULAR DAY OUT!

See reverse of coupon (page 14) for competition details. Cut-out or photocopy both pages and send entries to: RIAT005, Royal International Air Tattoo 99 Competition, RAF Benevolent Fund Enterprises, PO Box 1940, Fairford, Glos, GL7 4NA.

I am aged 18-40 ☐ 40+ ☐

DATA PROTECTION ACT 1998: From time to time the RAF Benevolent Fund Enterprises may wish to send you details of other events and services which they feel may be of interest to you. Please tick if you do not wish to receive this information. ☐

Name (Mr / Mrs / Miss) ____

Address ____

______________________________ Postcode: __________________

Write to:
Electronics and Beyond,
P.O. Box 777,
Rayleigh, Essex SS6 8LU

E-mail your views and comments to:
AYV@maplin.demon.co.uk

Give Science A Chance!

Dear Sir

If this is what Mr. Aldous really does, let's have some truly scientific investigation into 'things that go bump in the night" now!

Science has already proven that the 'hearing of voices' is nothing more than a clinical condition that causes the persons afflicted, to talk to themselves. Without doubt, the scriptures are full of individuals who either had this affliction, or were simply lying through their teeth.

Either way, we simply haven't got time to wait around, another few thousand years, until these present day fantasies become ancient mythology.

Yours aye,
Dougal Paterson.
Via e-mail

Why did David Aldous go to all the effort to come up with his detector if it was not a 'scientific' attempt to investigate the paranormal? In a few thousand years what you believe to be fantasies may well be scientific fact. We have not seen any conclusive proof one-way-or-the-other. Next month we will be publishing an interesting article by Graham Marett, for all you doubters!

Charged Up

Dear Sir,

I was surprised by the article ESD Tools - Are They Important? in issue 135 page 70. The article doesn't conform to what I had understood as the principles of electrostatic protection.

If a component is charged then this does not initially matter as long as all pins are at the same potential. If wrapped in something (such as conductive foam) that electrically ties all pins together then no harm will come when the entire chip/wrapper combination is brought to the same (earth) potential as the workbench, operator, etc.

The idea of a partially conductive tool offering a resistance "...of between $10^5\Omega$ and $10^7\Omega$..." is spurious. Wrist straps and similar earth drains are already fitted with a 1MΩ resistor, not for gently discharging electrostatic energy but to protect the operator. A direct 230V mains contact would be limited to causing a flow of 230μA through the operator's body, preventing a fatal shock. This works like a mains neon screwdriver tester in this respect.

So, a little more series resistance makes no real difference. The electrostatic voltage is extremely high but the amount of total charge is small. It's like a capacitor of a few pF charged to many thousands of volts. Remember the equation $Q/C = V$ giving a high voltage from a small charge if capacity is low. I think these tools are a menace. Someone could absent-mindedly pick one off the bench to repair a live circuit. Not being insulated (for example, to VDE standards as referred to in the article) a shock is possible, especially if resistance is only of the order of $10^5\Omega$. The best tools for static avoidance would be all-metal with no insulating grips on the handles. I hope you'll print this to see if anyone else agrees.

Dr. G. L. Manning
Edgware
Middlesex

I do not believe wrist straps came about to protect the user from the mains, but because of potential problems handling static sensitive devices - did any of us use them when playing with valve equipment? To be fair you cannot afford to be absent-minded when 'playing' with mains, or any high voltage equipment. Suppose the board you were working on was effectively at earth, and you were not, and nicely charged-up, where would the charge most likely leak too?

Mobile Charger

Dear Sir

Being on the move fairly regularly, I find the battery in the laptop computer will not last the day, and it is not always possible to arrange a recharge. As, it seems, most laptops require 17/18V at an amp or so to recharge the internal battery, this rules out the use of a 12V car battery.

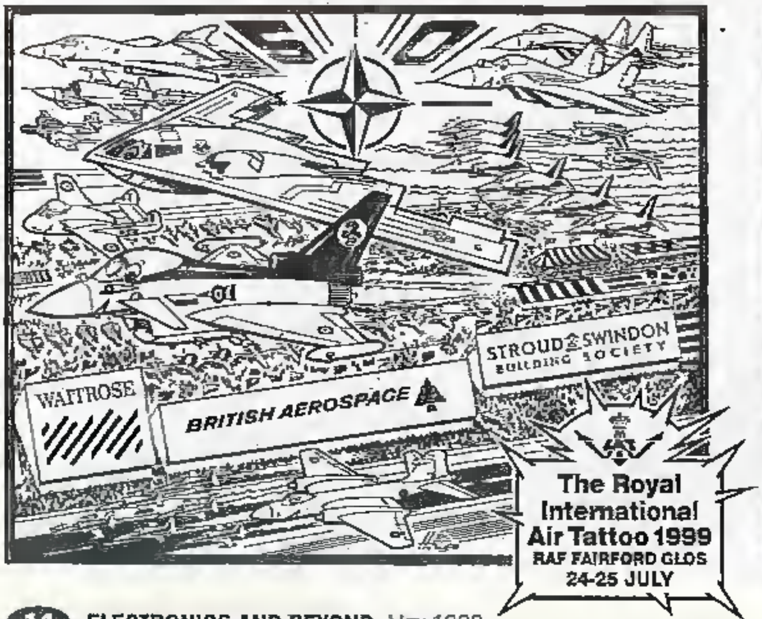
Perhaps the staff in your design department could come up with a project to enable the laptop to be charged from a 12V vehicle battery.

Colin Coker
Newton Abbot

A quick look at the latest Maplin Catalogue brought me to page 1125 where I found the LM2577 Step-Up Voltage Regulator (order code AD90X), which may well meet your requirements.

AIR TATTOO SPOT-THE-DIFFERENCE DRAW

(put 10 'X's on the right hand picture using a coloured pen to mark the difference.)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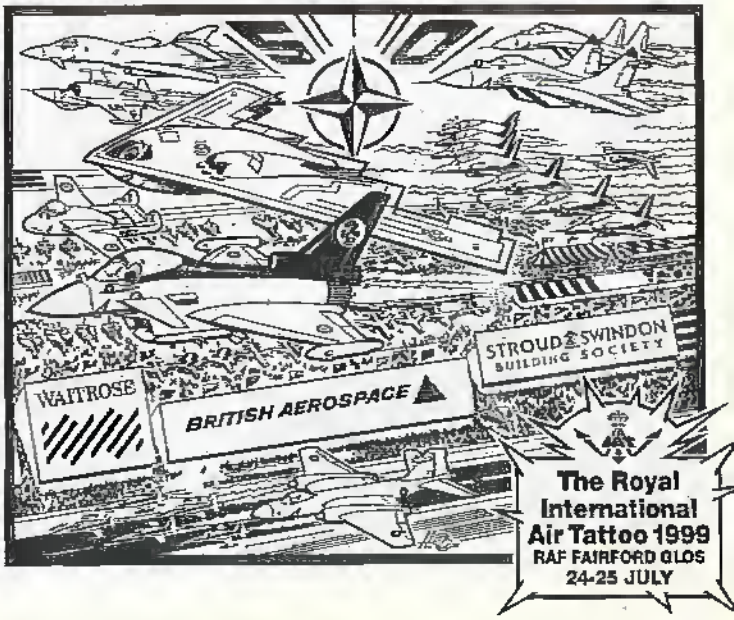
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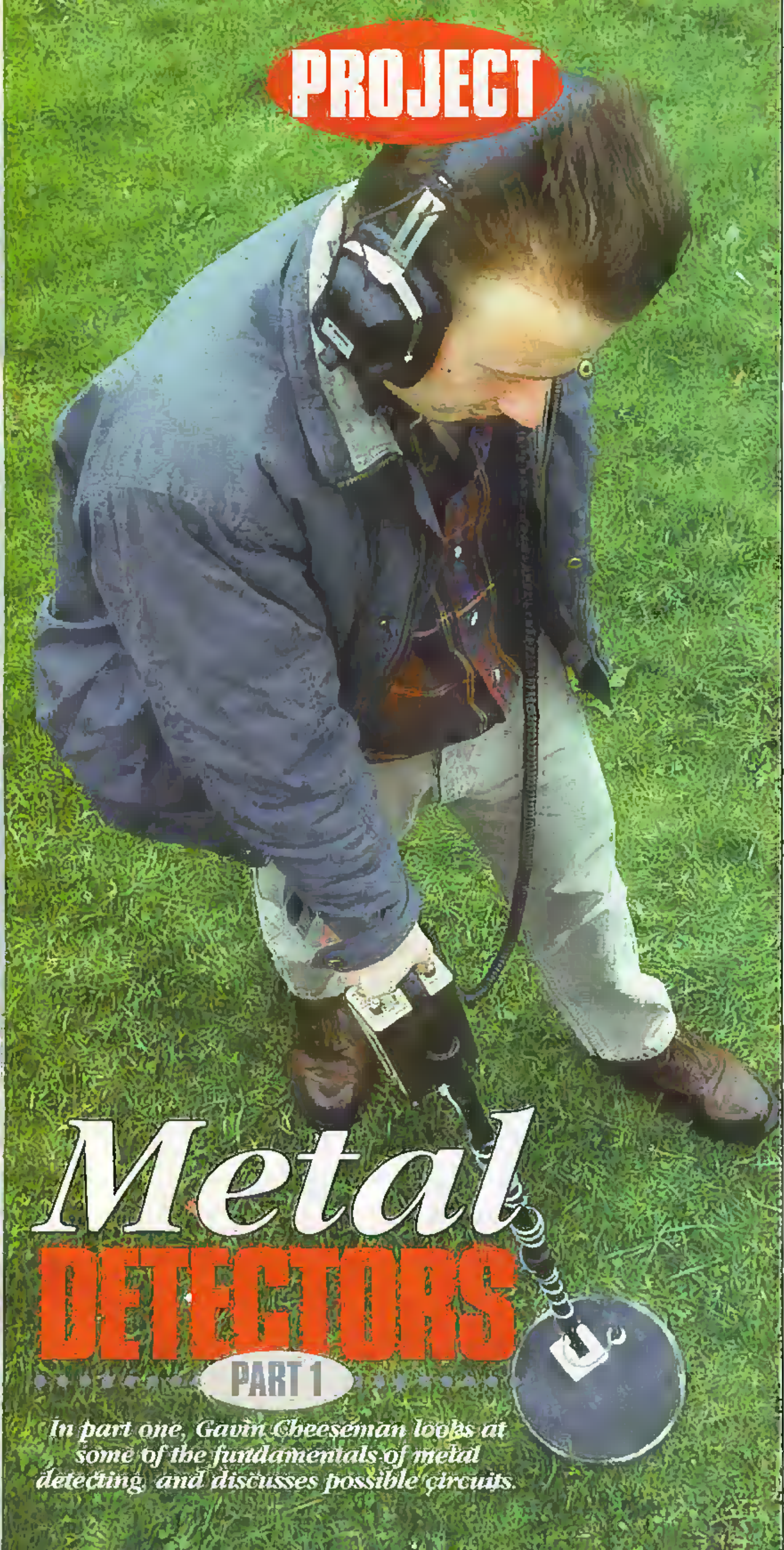


PROJECT

Metal DETECTORS

PART 1

In part one, Gavin Cheeseman looks at some of the fundamentals of metal detecting and discusses possible circuits.

Introduction

Metal detectors have many different uses ranging from detecting studs in walls to searching for archaeological artefacts or treasure buried in the ground. There are also many applications in industry. Over the years, a variety of different methods have been devised for remotely detecting and locating metal objects. The technologies used vary considerably depending on application. In this article we look at a selection of different types of metal detector and investigate the general theory behind the devices. Some practical considerations are also covered.

The simplest circuits are designed to detect the presence of metal objects independent of composition and do not provide any further information about the properties of the material detected. More specialised detectors allow discrimination between metals of different types or respond only to ferrous metals. The circuits and ideas discussed are intended as examples and may require considerable development and modification in order to produce a working unit.

Some Examples

Most simple metal detectors and some more specialised types make use of proximity effects whereby the presence of metal close to a search coil modifies the characteristics of the circuit. Metal detectors of the Beat Frequency Oscillator or BFO type operate using this principle. Figure 1 shows the block diagram of a simple metal detector using the BFO principle. The detector is based on the principle that the resonant frequency of a tuned circuit varies if a metal object is placed in close proximity. If the tuned circuit forms part of an oscillator then the output frequency will be modified by the presence of a metal object. The variation in output frequency depends on the oscillator frequency chosen. In general, the higher the frequency the greater the change and the more sensitive the circuit. However, if the frequency is too high, the practical range may be reduced by the absorption effects of soil, building materials etc. In a practical circuit, the oscillator often operates at a frequency well outside the range of human hearing and therefore it is necessary to provide some indication that the resonant frequency is changed. BFO metal detectors do this by mixing or 'beating' the output of the oscillator with that of a second (fixed frequency) oscillator to produce a mixing product or 'beat note' within the audible range. In simplified designs the functions of more than one of the stages shown may often be performed by one active component and the low pass filter may be as simple as a capacitor and a resistor.

The frequency of one of the two oscillators is normally adjustable to allow the most appropriate audio frequency to be selected. This is not simply for the comfort of the listener. Variations in pitch are more obvious at some frequencies than others. It is also possible to 'zero beat' the two oscillators so that the output is silent under normal conditions. When a metal object is detected, the frequency of the search coil oscillator changes producing an audible output corresponding to the difference in frequency between the two oscillators. When used in this way the detector will effectively be less sensitive as slight changes tend to result in only small changes in frequency. Therefore the audio note produced may be below audible frequency range. Also, depending on the design and coupling arrangements, there is sometimes a tendency for the two oscillators to automatically lock to the same frequency. If this occurs, a considerable change in the resonance of the search coil tuned circuit is required to pull the oscillators out of lock and onto different frequencies. Once again, this effect results in reduced sensitivity but can be useful in some applications.

Figure 2 shows a circuit example of a detector based on the beat frequency principle. The circuit shown is intended to illustrate how simple design techniques may be used to produce this type of detector. Component values shown are approximate. Because some parameters will vary depending on the chosen operating frequency, some values are omitted.

Inductor L1 forms the search coil and is resonated by variable capacitor VC1 to form a high Q tuned circuit. The tuned circuit forms part of an oscillator stage based around field effect transistor TR1 and associated components. VC1 allows the operating frequency of the oscillator to be varied. A second oscillator stage is formed by L2, C4, C5, R4 and TR2, this time operating at a fixed frequency. The output of the two oscillator stages is fed to D1 via limiting resistors. D1 introduces a non-linear element into the signal path that effectively mixes the two oscillator frequencies. The result is an output rich in frequencies corresponding to the sum and difference of the two oscillator frequencies and associated harmonics. The oscillators are tuned to operate on closely adjacent frequencies such that the difference frequency falls within the audible region. For example if one oscillator is tuned to 100kHz and the second oscillator is tuned to 101kHz this will result in a difference frequency of 1kHz. The output of the diode mixer is fed to an audio amplifier comprising IC1 and associated components. This stage is based around a standard operational amplifier and would normally be capable of driving a high impedance earpiece or headphones. The value of capacitor C9 is chosen to limit the response of the amplifier at high frequencies which could otherwise result in undesirable effects. The gain required from the audio amplifier will depend on the amplitude of the signal at D1. This in turn depends on the oscillator frequency and the Q of the tuned circuits amongst other factors. The gain of the audio amplifier is determined by the value of resistors R7 and R10. In some applications it may be desirable to drive a small loudspeaker. Where this is the case the output at P3 could be connected to a small power amplifier.

Because the design of the circuit is very simple it will tend to suffer from problems such as frequency drift. This is not always a serious problem. However, where necessary unwanted drift can be reduced considerably by regulating the supply voltage and using high tolerance capacitors with the appropriate temperature coefficient. Component layout also plays an important part.

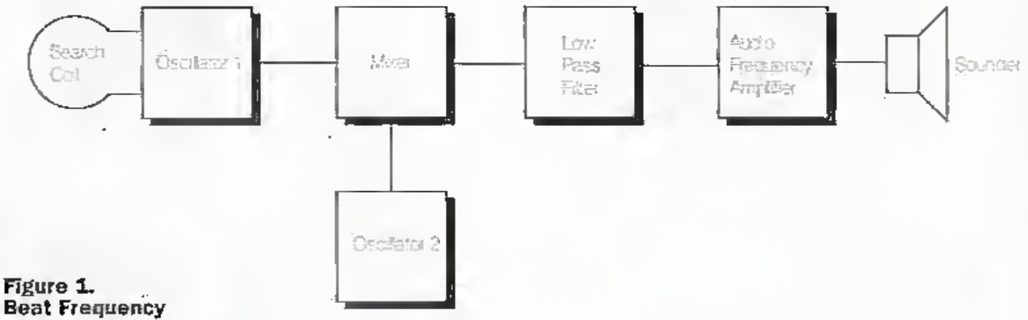


Figure 1. Beat Frequency metal detector block diagram.

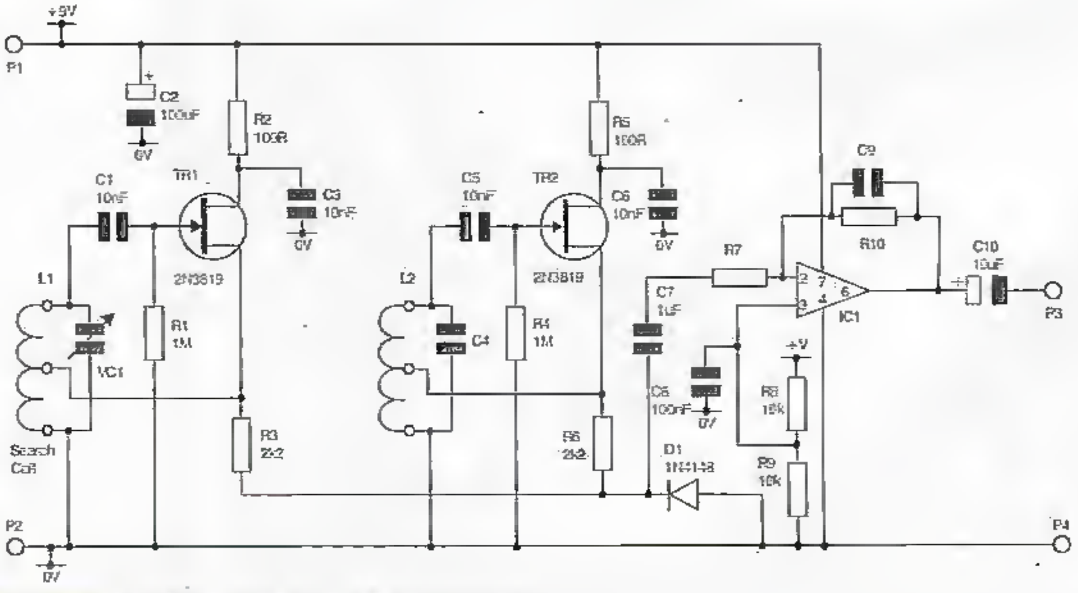


Figure 2. Illustrative example of Beat Frequency metal detector circuit.

Search Coil Design

The size and form of the search coil depends on the required sensitivity of the detector and on dimensional restrictions determined by the application. Also, different types of search coil provide varying degrees of accuracy. For example, the coil used in a simple handheld detector of the type often used in the building industry is normally relatively small so as to allow for compact construction and accuracy when determining the position of metal objects in walls etc. Conversely detectors used for locating objects buried in the ground normally have much larger search coils to provide high sensitivity and are not usually required to be particularly compact. However, a larger diameter coil may mean a reduction in accuracy. The shape of the coil can also have considerable influence on the overall response of the detector. A simple linear coil wound on an open former may be used for a hand held unit where it is intended for use at close range. In more specialised metal detectors, circular or square search coils are common.

A further consideration in relation to search coils forming part of a resonant circuit is the affect of non metallic objects on the Q and resonance of the tuned circuit. These effects are often related to capacitive loading of the circuit by nearby objects and can result in spurious operation whereby the circuit acts as if it is detecting metal when there is in fact no metal present. Capacitive effects can be reduced by the use of an earthed non-ferrous shield placed around the search coil. This shields the coil from electrostatic influences but has negligible effect on the magnetic characteristics of the circuit.

Other Resonant Detectors

There is another form of detector that also makes use of the detuning effects of metal on a resonant tuned circuit. Figure 3 provides a conceptual illustration. A fixed frequency oscillator is used to drive a tuned circuit comprising the search coil and a variable capacitance. The inductance of the search coil and the associated capacitor are chosen so that the tuning range of the tuned circuit covers the oscillator frequency. In use the detector is placed in a position away from metallic objects and the tuned circuit is adjusted to resonate at the oscillator frequency using the variable capacitor. When correctly adjusted, this results in a peak in output signal level. Moving the search coil close to a metal object results in a shift in the resonant frequency of the tuned circuit; however, this time the oscillator frequency is fixed and as a result the signal level developed across the tuned circuit drops. For the circuit to work effectively, the oscillator must exhibit good frequency stability. A simple method to ensure that the frequency remains stable is to use an oscillator circuit based on a quartz crystal. Relatively simple but effective detectors providing a reasonable level of sensitivity can be produced using this principle. As with most simple metal detectors, the sensitivity is determined by the size and shape of the search coil. The practical sensitivity of the circuit is also determined by the method of indication. For example, the voltage developed across the tuned circuit could be buffered, rectified and used to drive a moving coil meter. With careful circuit design making use of stable, high tolerance components it is possible to achieve good sensitivity. The voltage produced could also be used to drive a voltage controlled audio frequency oscillator to give an audible indication.

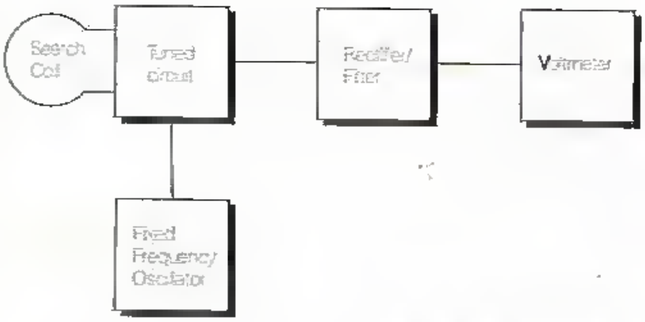


Figure 3. Block Diagram of a resonant detector using a fixed frequency oscillator.

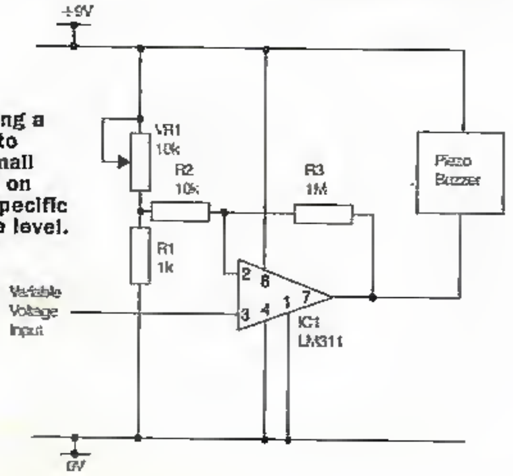


Figure 4. Using a comparator to operate a small piezo buzzer on reaching a specific input voltage level.

It is also simple to set a 'detect' threshold by connecting a comparator to the DC output of the circuit. An example of how this may be achieved is shown in Figure 4. By setting a specific switching threshold for the comparator, the circuit can be arranged to produce a

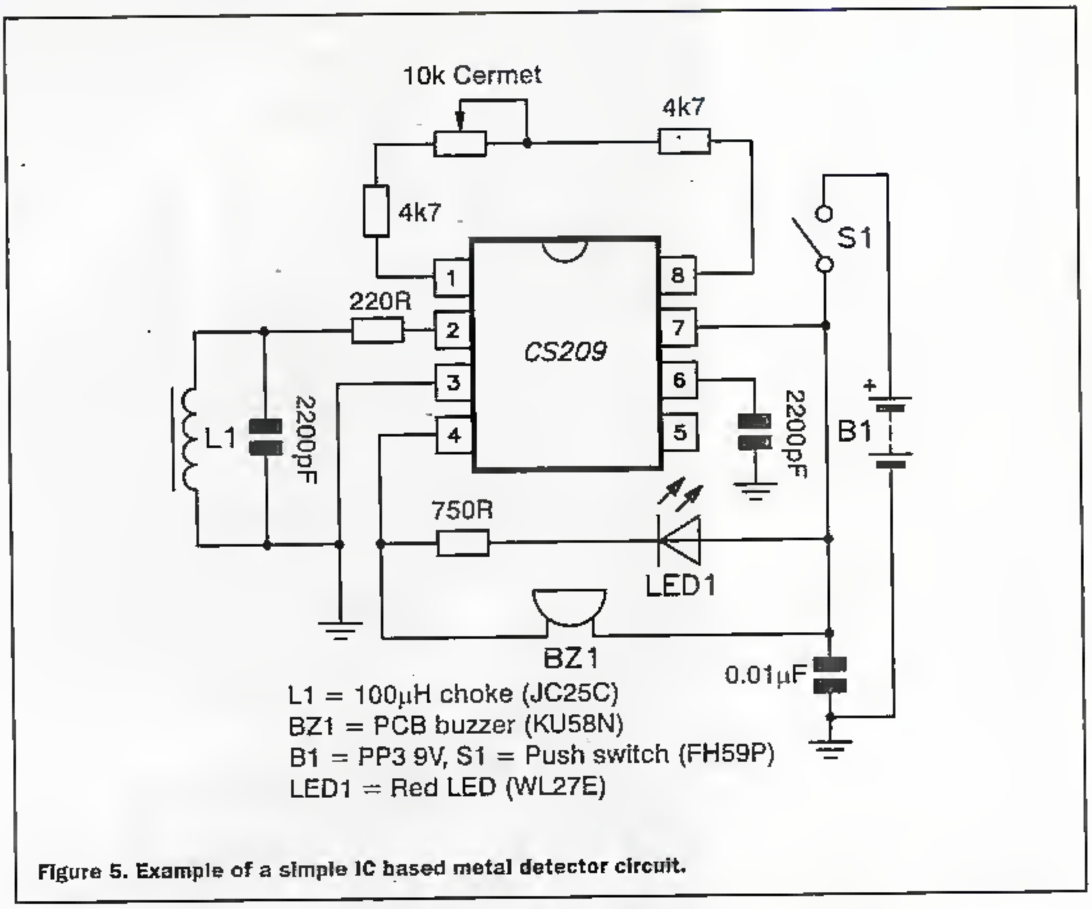


Figure 5. Example of a simple IC based metal detector circuit.

switched output when metal is detected. In the example this is used to drive a small piezo buzzer. R1 and VR1 determine the switching threshold. R3 provides hysteresis to prevent the comparator oscillating around the trigger point. Using this principle, the sounder remains inoperative until a metal object is detected that is large enough to drive the comparator input over a predetermined switching threshold. By making the switching threshold adjustable, different levels of sensitivity may be set.

IC Based Metal Detectors

Off the shelf IC's are available that are designed specifically for use in metal detector circuits. An example is the CS-209A IC (Maplin stock code UH59P). The device makes use of the fact that metal in close proximity to an oscillator tuned circuit affects the Q of the circuit and hence the signal amplitude. A level detector monitors the oscillator output and switches when a preset threshold is reached. An example of a simple circuit using the IC is shown in Figure 5 for reference. The device is ideal for use in applications such as hand held detectors for searching out wires and studs in walls.

Detectors making use of variable coupling

A slightly different design makes use of variations in the degree of coupling between two coils when metal is placed in close proximity. There are various arrangements for this type of circuit which is sensitive to ferrous metals. The block diagram of a detector using this principle is shown in Figure 6. The output level from coil 2 is monitored. When a ferrous metal object is placed close to the coils the output level from coil 2 increases with the coupling. The unit may be set to trigger an audible or visible indication when the output level from the coil reaches a preset threshold. A moving coil meter or bargraph display may also be used to provide a level indication. This type of detector is generally not suited to applications requiring high sensitivity and has few practical advantages over other detector types.

Magnetometer Based Detectors

All of the detectors mentioned so far work by directly affecting the characteristics of components in the metal detector circuit. These provide good general purpose performance in a wide range of applications. However, they are only really suitable for use over a short range where the metal object is relatively close to the detector. Therefore, if you are trying to detect metal buried deep in the ground (metres as opposed to centimetres) different techniques are required.

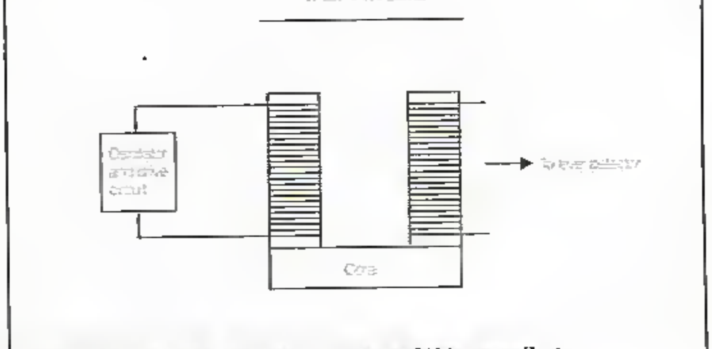


Figure 6. A simple detector using variable coupling.

One method of detecting large ferrous objects buried deep in the ground is to look for localised variation in the earth's magnetic field. Sensitive magnetometers may be used to measure variations of this type. Because field variations may be very small, detectors of this type can be somewhat complex to construct. Also, the detectors can often be influenced in an unwanted way by ambient magnetic fields from power lines, geological features etc. Nevertheless, if you are looking for something large and iron buried deep in a remote location, a magnetometer based metal detector may provide the best chance of finding it.

Techniques used to produce magnetometers are varied. Linear hall effect devices that produce an output voltage proportional to magnetic flux are readily available in IC form. These are convenient but produce a relatively small output voltage. Therefore, to provide reasonable performance, when the changes in the magnetic field are small it is often necessary to follow the hall effect device with a low noise, low offset DC amplifier. Other devices for the measurement of magnetic fields include Flux Gate and Proton magnetometers. These can provide good sensitivity when properly aligned.

One of the easiest ways to detect localised variations in the earth's magnetic field is to compare the output from two magnetometer sensors spaced some distance horizontally apart, as illustrated in Figure 7. When the magnetic field is undistorted, the output from both sensors is similar (once any differences due to tolerance are ironed out). However a metallic object positioned immediately below one of the sensors results in distortion of the field and a variation in magnetic flux. Because the distortion is localised and one of the sensors is closer to the metal object than the other, a difference in the output of the two sensors results. This difference can be amplified to provide an audible or visible reading.

In addition to the presence of ferrous metal objects, there are also other possible reasons for

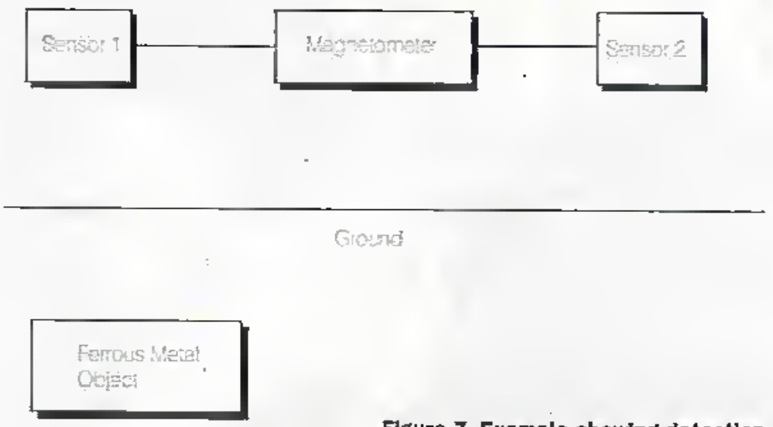


Figure 7. Example showing detection of ferrous objects using two magnetometer sensors.

localised variation of the earth's magnetic field. Therefore magnetometers of the type discussed can only be used to indicate where objects may possibly be buried and do not give 100% certainty. Also, as with most metal detectors, it is sometimes difficult to distinguish between a small object buried near to the surface and something larger buried several metres deep.

Indicators and Interpreting Results

How a metal detector indicates that it has detected a relevant object can be quite important. In most cases the output from the detector circuit may be used to drive an appropriate meter. This could be a simple analogue meter, a bargraph or a digital display. In most applications, however, it is not practical to watch a meter reading all the time. If the circuit provides a switched output that becomes active when a metal object is detected, this may be used to switch on a lamp or buzzer. An audible indication is often much more appropriate, especially if you are walking around a field looking for buried coins. In this situation, probably the last thing you need is to continuously watch a meter. As we have seen, some types of metal detector, such as the beat frequency type, automatically produce an audible output and for these units this is the normal mode of operation. It can still be useful to have a meter reading in addition to help the user determine the degree of response when an object is detected. For metal detectors that produce an output in the form of a variable voltage, this can easily be converted to an audible output using a voltage controlled audio frequency oscillator. This will produce a note that varies in pitch similar to the BFO unit when an object is detected.

Using peak hold techniques it is possible to make the response of a metal detector dynamic to aid pinpointing of a find once it has been detected. Multiple search coils can also be used. These may be switchable so that, for example, a large coil is used to initially detect the presence of metal whilst a smaller coil provides more accurate pinpointing of the find.

Magnetometers are sometimes used to detect very large ferrous objects or mineral deposits. Interpreting and making sense of the data produced in such circumstances can be very complex. In this type of specialised application, it is useful to provide a digital interface so that the reading and precise location can be stored in memory and loaded onto a personal computer for processing.

Discriminating between different materials

For some applications it can be useful to discriminate between different types of metal. As mentioned, some types of detector will only respond to ferrous metals. Also metals of different types result in different proximity effects. For example, the variation in frequency produced when a metal object is close to the search coil of a BFO based detector will not only depend on the size and position of the object but also on its composition. Ferrous metals (containing iron) produce a totally different response to non-ferrous metals such as copper, gold and silver. This effect can be used to great advantage when searching for precious metals (coins etc.) buried in the soil.

Housing Considerations

So far we have covered some electrical design criteria and fundamental theory relating to metal detectors. Of course, when producing a practical unit, the physical aspects of construction are almost as important. A metal detector should be constructed and housed so as to be as simple to use as possible. For example, a detector designed for DIY use in the home should preferably be compact enough to fit in your tool box. Conversely, if the unit is designed for outdoor use, it is important to consider such aspects as weatherproofing. Some applications may require the search coil to be submerged in water requiring complete waterproofing. If your hobby is searching for buried treasure you will want the detector to be as light weight as possible and so on. An example of a typical layout is shown in Figure 8. The shape and dimensions of some metal detectors are heavily influenced by the design of the circuit itself. This is particularly the case with some magnetometer based units and detectors requiring large search coils. Although these considerations may be fairly obvious, they are an important factor and can affect the circuit layout considerably.

Next Month

This month we have looked at the basics of metal detector design so as to form an overview of the type of techniques commonly used. Next month we will look at the construction of a metal detector and consider specific requirements at a practical level.

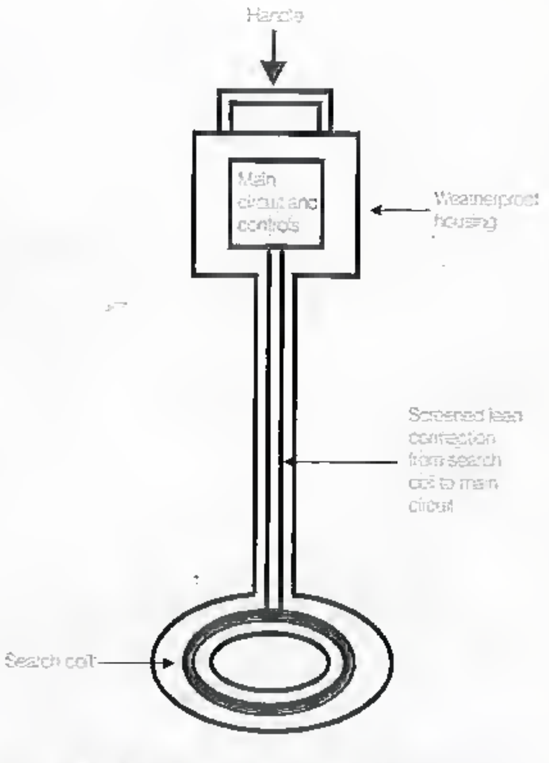

Handle
Main circuit and controls
Weatherproof housing
Screened lead connection from search coil to main circuit
Search coil

Figure 8. Typical layout of a metal detector used for treasure hunting.

DV & D-VHS

Reg Miles looks at the latest development in digital video and digital VHS.

Photo 1. JVC GR-DVF10 with 160x digital zoom.

Photo 2. Canon MV1 with interlace/progressive CCD.

Although consumer video - VCRs and camcorders - is still firmly ruled by VHS and 8mm, that is beginning to change with the Digital Video (DV) format making inroads into the camcorder market, and Data-VHS waiting in the wings to record the new digital TV channels.

Digital Video

DV, like 8mm, is a committee-developed format. And, uniquely, it now encompasses all markets from consumer to broadcast.

Preliminary discussions on standardisation began in 1990 between four of the companies that had been working independently on digital video: Matsushita (Panasonic), Philips, Sony and Thomson. Shortly after they were joined by Hitachi, JVC, Mitsubishi, Sanyo, Sharp and Toshiba and formed the Digital Video Cassette Consortium. Which led in 1994 to agreement by the, then, 52 companies on standards for SD (Standard Definition) and HD (High Definition) formats at the HD Digital VCR Conference. Leaving the specifications for two additional formats, for European DVB (Digital Video Broadcasting) and American ATV (Advanced Television digital HD broadcasting), to be finalised nearer the launch of those services. And in 1995 the first DV camcorders appeared on world markets (the 'Cassette' part of the name having been dropped).

They were more expensive than consumers had been used to; but then the quality was greater and they incorporated more features. For full advantage had been taken of the changeover to digital.

Technically Superior

The horizontal resolution of DV is about 500 lines: this compares with just over 400 lines for Hi8 and S-VHS, and around 250 for 8mm and VHS. And the colour bandwidth of 3MHz is six times that of the analogue formats. The audio is no less impressive, with 48kHz 16-bit linear PCM stereo sharing the tracks (Figure 1a); and, depending on the hardware, the additional choice of recording and/or playing back at 44.1kHz or 32kHz. There are also two 32kHz 12-bit non-linear stereo channels (Figure 1b). If a recording is made using the latter, then fresh audio can be dubbed onto stereo 2 during post-production, leaving the original on Stereo 1.

Time Base Corrector

A timebase corrector (TBC) is a standard feature for playback because the format is pushing the limits. This retimes the digital video signal coming off the tape to correct for equipment fluctuations and so minimises horizontal jitter. There is also error correction to minimise dropouts - momentary losses of signal caused by dust on the tape or damage to its surface. This is the ubiquitous Reed Solomon variety, which works on symbols (groups of bits) and thus deals very effectively with burst errors, such as dropouts, where a lot of errors are confined within a small area and affect only a limited number of adjacent symbols.

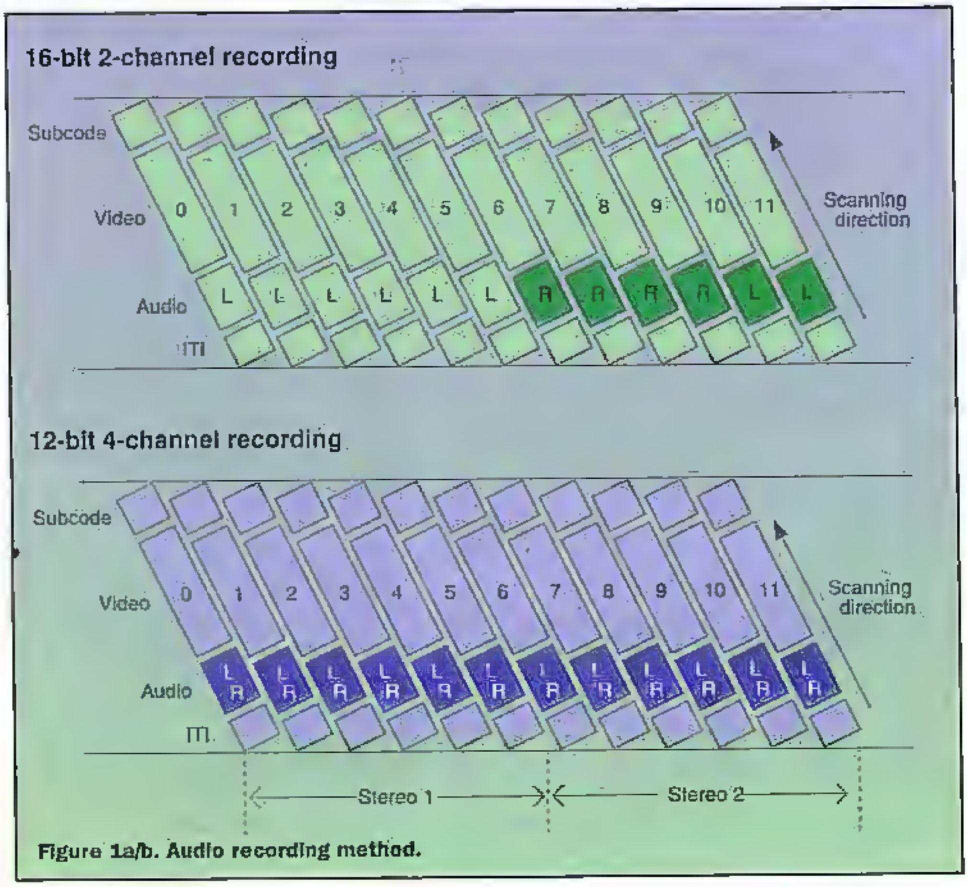


Figure 1a/b. Audio recording method.

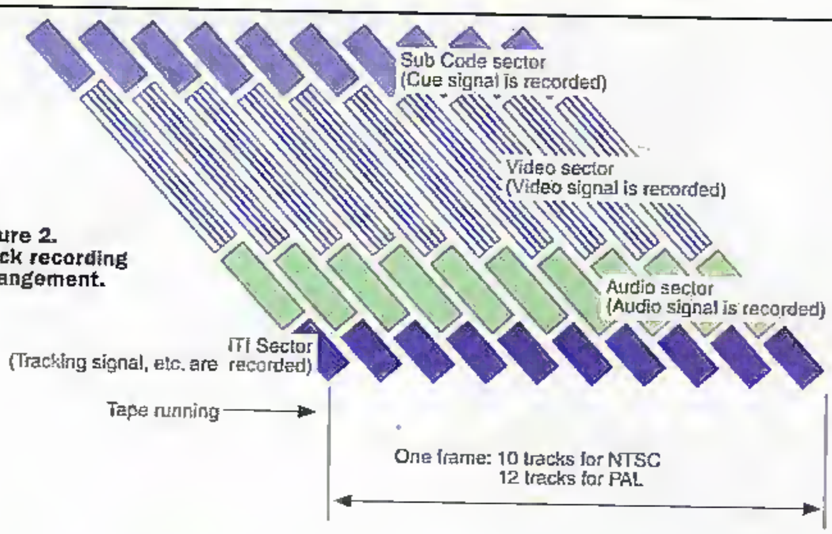
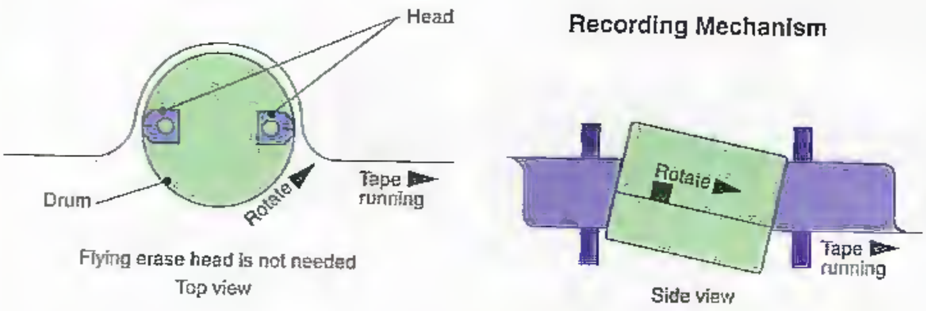

Sub Code sector
(Cue signal is recorded)
Video sector
(Video signal is recorded)
Audio sector
(Audio signal is recorded)
ITI Sector
(Tracking signal, etc. are recorded)
Tape running
One frame: 10 tracks for NTSC
12 tracks for PAL

Figure 2. Track recording arrangement.



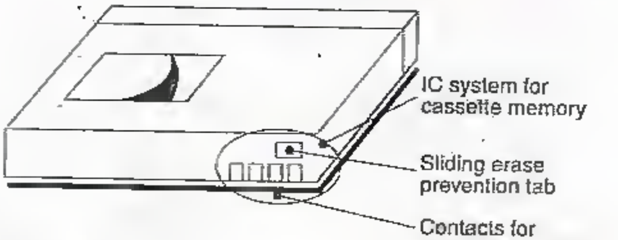

IC system for cassette memory
Sliding erase prevention tab
Contacts for IC cassette memory

Figure 3. Cassette IC memory.

Surprisingly Small!

The early consumers must have been surprised by how small the Mini DV camcorder cassette is, for at 66x48x12.2mm it makes even the 8mm and VHS-C cassettes seem large. Even the full size DV one is noticeably smaller than VHS. Unusually, the recording times are the same for PAL and NTSC. This is because 300 tracks per second are recorded for both: 12 tracks per frame for 25Hz PAL and 10 tracks per frame for 30Hz NTSC (Figure 2). Giving maximum recording times of 60 and 270 minutes (there is now an 80 minute Mini DV cassette; and LP increases times by 50%). And both cassettes can be used in a DV VCR without an adapter for the Mini one.

The cassettes offer more than just size advantages, however. They are closed types to keep out dust. They can also include a built-in IC memory (Figure 3). This includes all the physical information about the tape, but also allows for a table of contents (TOC) to be written and read, giving rapid access to scenes, plus any other data that the manufacturer thinks should be written to memory. The memory capacity can vary, but the size in bits is printed on the cassette (16k seems to be the maximum at present).

Photo 3. Sony GV-D900 DV Video Walkman.

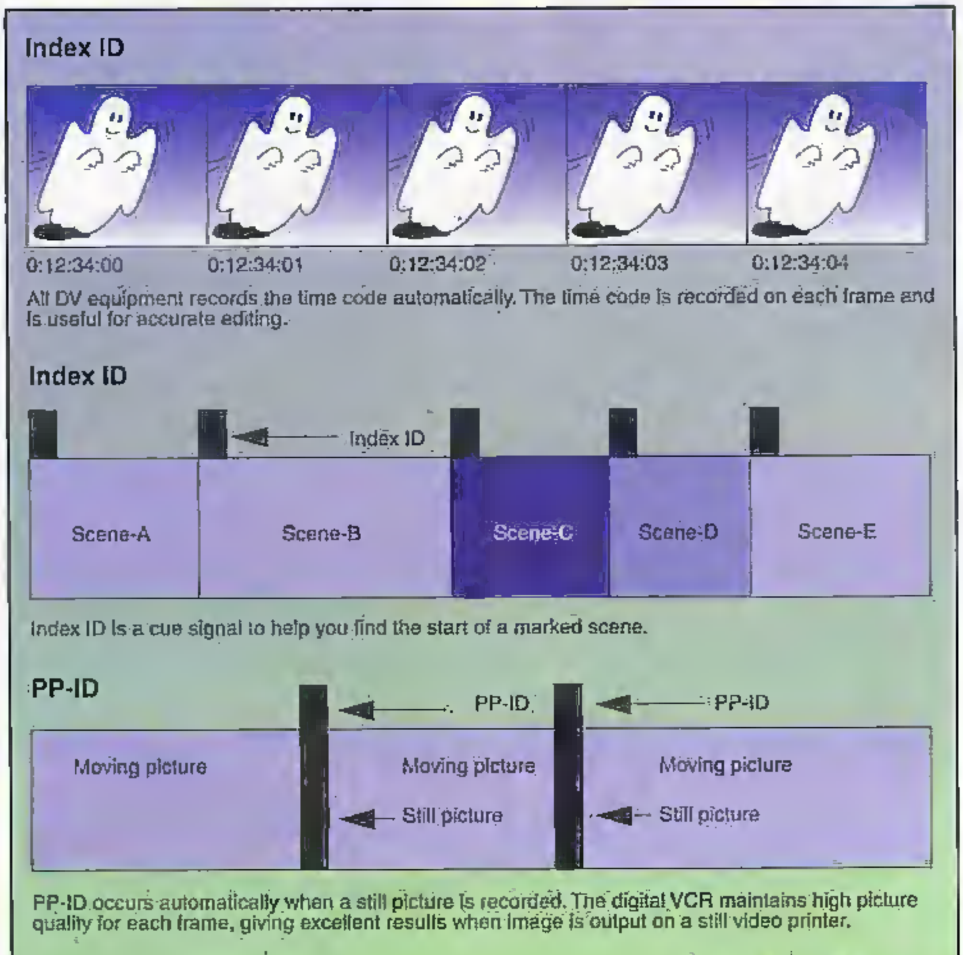
Even without cassette memory high speed access is possible using the data recorded in the sub code sector of the tracks. This contains an index signal marking the beginning of each scene; timecode, which marks every frame in hours, minutes and seconds, plus frame number - 1-25; and the position of still pictures amongst the moving images (Figure 4). This last is another new development: a single image is memorised and then recorded for several seconds, along with ambient sound, using frame mode for greater definition. Canon and JVC have recently launched models with a CCD that can be switched between interlace and progressive scanning: thus maximising the quality of still pictures, and those moving images that are likely to be played in still or slow motion. Many of the latest models can also record a burst of still pictures.

Video auxiliary data is recorded in the video sector of the tracks. The standard data consists of the date and time when the recording was made, a recognition ID when widescreen mode is used, and the input source - such as channel number. Optional data is mainly camera information - shutter speed, etc. All of which can be displayed on screen or hidden. The same applies to audio auxiliary data; this being recorded in the audio sector of the tracks.

Lastly, the insert and track information (ITI) sector (actually, this is recorded first, the heads travelling up the tracks). This is mainly the auto tracking data to maintain head and track alignment. But it also includes data about inserts. With the tracks divided into sectors it is a straightforward matter to insert new video (Figure 5) or audio or both into existing material without causing any glitches (if the equipment allows it). These, and straightforward assemble edits, being aided by the timecode and search facilities.

Digital Out

With quality being maintained by the use of the DV terminal to send video, audio and all the additional data on the tape in digital form. Always assuming the user has two camcorders, one with DV in/out, or a DV VCR. It is more likely that the material will be decompressed and converted to analogue for editing onto VHS or S-VHS. The first camcorders either had just DV out or an analogue output and the first VCRs were only launched last year, so there has not been much scope to experiment with digital editing and multi-generation copies.



All DV equipment records the time code automatically. The time code is recorded on each frame and is useful for accurate editing.

Index ID is a cue signal to help you find the start of a marked scene.

PP-ID occurs automatically when a still picture is recorded. The digital VCR maintains high picture quality for each frame, giving excellent results when image is output on a still video printer.

Figure 4. Sub-code sector.

The DV terminal is based on the IEEE1394 standard for data throughput of up to 400Mbps (known also as i.Link or Firewire). It allows equipment to be connected up in similar fashion to a computer network - up to 64 items in total. And the equipment to be intefaced with a compatible computer for non-linear editing. Eventually it is expected to form the link between all home multimedia products - digital TV, DVD, etc, passing not only video and audio but control signals, too. Some equipment also has an RS232C terminal for exporting still pictures to a computer's serial port. Cameras have also appeared that can output still pictures or grabbed frames to a storage unit: Sharp has one that contains a 2MB flash memory, and Sony has one that incorporates a standard floppy disk drive.

In addition to being the first digital format for consumer use, DV is also the first consumer format to use component recording. This keeps the luminance (Y) signal separate from the chrominance signal, and divides that up into its colour difference components - R-Y and B-Y (or Cr and Cb) - Figure 6. Having three separate signals allows a wider colour bandwidth, eliminates cross colour and cross luminance artifacts, and obviates the need to encode and decode as would be the case with a composite signal - thus minimising degradation and making it easier to edit and manipulate.

Once in component form the signals are sampled and quantised. The luminance is sampled at 13.5MHz. The colour difference signals are sampled at 6.75MHz: this sampling of alternate pixels effectively halves the horizontal resolution by comparison with the luminance; the resolution is then halved vertically by only sampling Cr and Cb on alternate lines - a 4:2:0 sampling structure (Figure 7). This is used to keep down the data rate and, ultimately, the cost.

Sampling rates are recommended by the CCIR601 standard. These are based on a fundamental frequency of 3.375MHz; with a minimum sampling rate of four times that, 13.5MHz, necessary to avoid any quality loss (although colour is not so critical). However, DVs 8-bit quantisation of the luminance and colour difference signals does conform to the minimum recommended by CCIR601 for a good cost/quality performance.

DV is also the first consumer format to employ direct compression (the analogue formats have all reduced the luminance and colour bandwidths and employed various other tricks to minimise the amount that is recorded). DV is not above employing a trick or two itself: one of those being to only compress the picture area that will be visible on the TV screen. The discrete cosine transform (DCT) method is then used to prepare the picture for compression proper, because of its ease of computation. A ratio of 5:1 is applied, which reduces the video transfer rate to 25Mbps. Coding is done on an intra-frame basis: this does mean that motion artefacts can occur if there are differences between fields due to rapid subject movement, and editing can be more difficult than with the alternative intra-field system - but it is better than the analogue formats.

When it has been error corrected the whole lot is recorded onto the 1/4in wide metal evaporated tape by two heads on a 21.7mm diameter drum rotating at 9000rpm. This gives a writing speed of 9.9m/s. The track pitch is 10μm for SP and 7μm for LP; with tape speeds of 18.8mm/s and 12.6mm/s respectively.

Professional News Gathering

Going back to 1993, Matsushita decided that DVC also had the potential to make a professional news gathering and field acquisition format. The equipment would be smaller and lighter than other professional equipment; and it would be cheaper, not only because of the compromises necessary to make it viable as a consumer product, but also because it would have that mass production base. After canvassing the opinions of various broadcast and news organisations they showed the first prototypes in 1994, and began delivery in 525 line markets in 1995 and in 625 line markets in 1996.

DVCPRO is essentially a beefed-up version of the standard format. The track pitch is increased to 18μm and tape speed to 33.8mm/s (there is only the one speed). And metal particle tape has been substituted for ME. The sampling structure has been changed from 4:2:0 to the 4:1:1 that is used for the NTSC version of consumer DV. This means that Cr and Cb are sampled at 3.375MHz; reducing the horizontal reolution to one quarter that of the luminance, but without affecting the vertical resolution. This allows more intensive post production, at the expense of a reduced colour bandwidth. Other changes are the

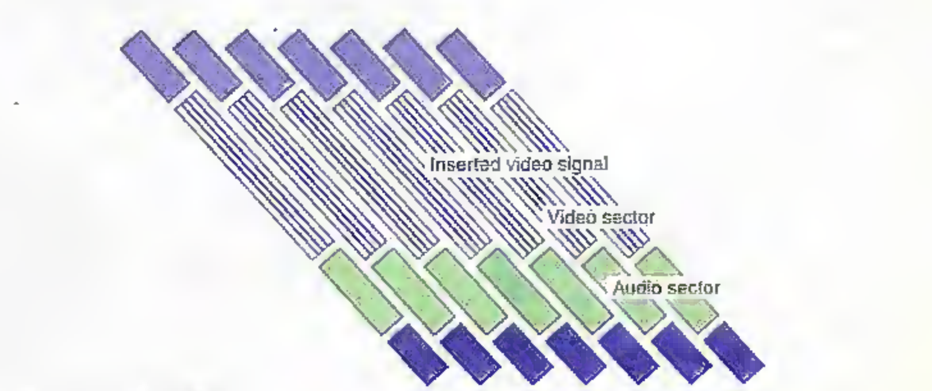


Figure 5. Video Insert.

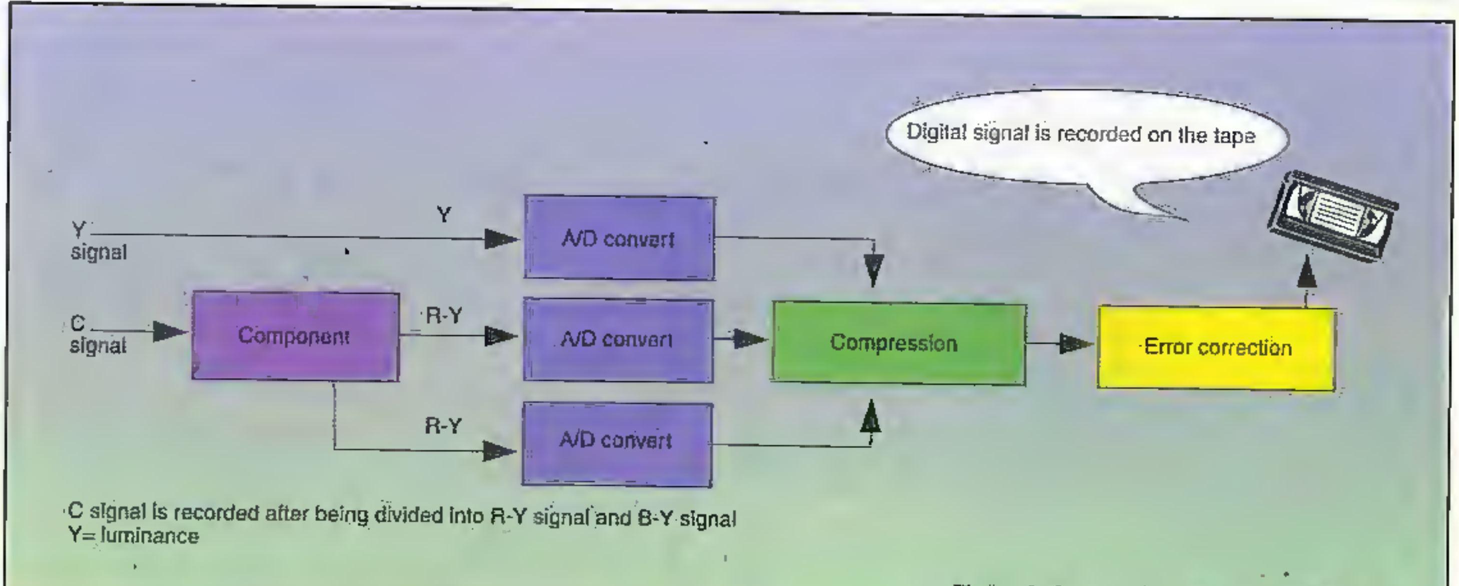

Digital signal is recorded on the tape
Y signal
Y
A/D convert
C signal
Component
R-Y
A/D convert
Compression
Error correction
R-Y
A/D convert
C signal is recorded after being divided into R-Y signal and B-Y signal
Y= luminance

Figure 6. Component video recording method.

Photo 4. Panasonic AJ-D700 used by Visage for electronic news gathering (ENG).

addition of an analogue audio cue track to give access to audio during fast winding, and to provide a third low quality channel; the recording of linear and vertical interval industry standard timecodes (LTC and VITC) in the sub code sector; the addition of a control track to enable faster servo lock after mode transitions; and the option of a serial digital interface (SDI) - the broadcast standard.

In 1996 Sony launched its professional version - DVCAM. This is essentially the same as the consumer format, apart from 15µm tracks, a tape speed of 28.22mm/s, and a more advanced metal evaporated tape. It also introduced a feature called 'ClipLink': this captures a small index picture from the first frame of each shot and stores it in camera memory, along with shooting data - timecode, shot and take numbers, etc; as the cassette is ejected all the index pictures (up to 198) are recorded onto the tape in a maximum of seven frames, and the shooting data is written to the cassette memory. Panasonic have since launched a similar shot logging system - 'DVpix Link'.

Dockable VCRs

Both DVCAM and DVCPRO will play DV tapes (SP only), and DVCPRO will also play DVCAM tapes. The range of equipment from both Sony and Panasonic has increased rapidly: with dockable VCRs that can be mated to a variety of cameras, camcorders, VCRs, edit VCRs, non-linear disk-based editing systems, hybrid disk/tape editing systems and players. Much of it making use of the serial data transfer interface (SDTI), which handles compressed video, sub code and audio without change; and which allows dubbing at four times normal speed with some VCRs.

JVC has launched a dockable DV VCR, and together with Panasonic and Sony, include uprated consumer DV camcorders in their ranges - being small and unobtrusive these can be useful in certain situations. While Canon has a 'prosumer' camcorder with a new interchangeable lens range.

In 1997 Panasonic launched DVCPRO50: a variant aimed at top professional and low end broadcast users, based on the 50Mbps HD specification. This requires advanced

Photo 5 Sony DVCAM equipment.

ME tape, running at 37.6mm/s, with a four head drum recording 20 10μm tracks per frame. The sampling frequencies are 40.5MHz for luminance and 13.5MHz for the chrominance signals, using 8-bit quantisation. The audio specifies four channel 16-bit 48kHz, and eight channel 12-bit 32kHz. Panasonic's DVCPRO50 version runs the tape at double the HD speed (4x standard), has a 4:2:2 sampling structure, 3.3:1 DV-based intra-frame compression, and four 16-bit 48kHz audio channels. The equipment will also record and play at 4:1:1/25Mbps, and will play standard DVCPRO recordings.

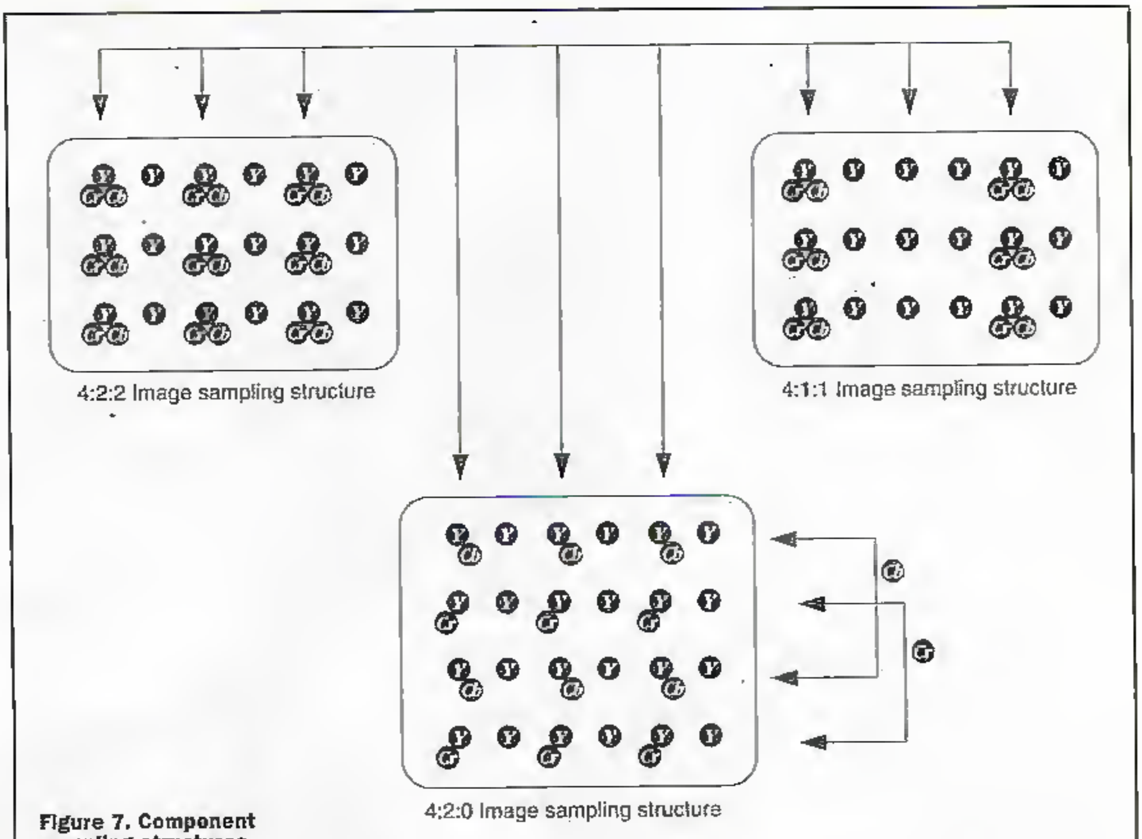

Y
Cr
Cb
4:2:2 Image sampling structure
4:1:1 Image sampling structure
4:2:0 Image sampling structure

Figure 7. Component sampling structures.

Digital VHS

Returning to domestic recording, Philips, and probably other less forthcoming companies, plan to launch D-VHS before the end of this year. To maintain compatibility this will be added to VHS or VHS/S-VHS VCRs. D-VHS has been developed by JVC - the inventors of VHS, with technical advice from Grundig, Hitachi, Matsushita and Philips, and support being expressed by most of the others.

Technically D-VHS is unlike other digital formats in that it does not format the data but records a bitstream. In this case an MPEG-2 transport stream which, apart from Reed Solomon error correction and an embedded scrambling mechanism for copy management, is recorded exactly as it is received and is output in the same state. The reasoning behind this is that consumers will already have set-top boxes or integrated TVs capable of decompressing MPEG-2 so there is no point in repeating it. The data will be taken from the box or TV via IEEE1394, recorded, and played out to the box or TV via IEEE1394 (Figure 8). Because the data is the same there is no getting around charges for encrypted material. It will also make it easier for the programme providers to change the signals, adding

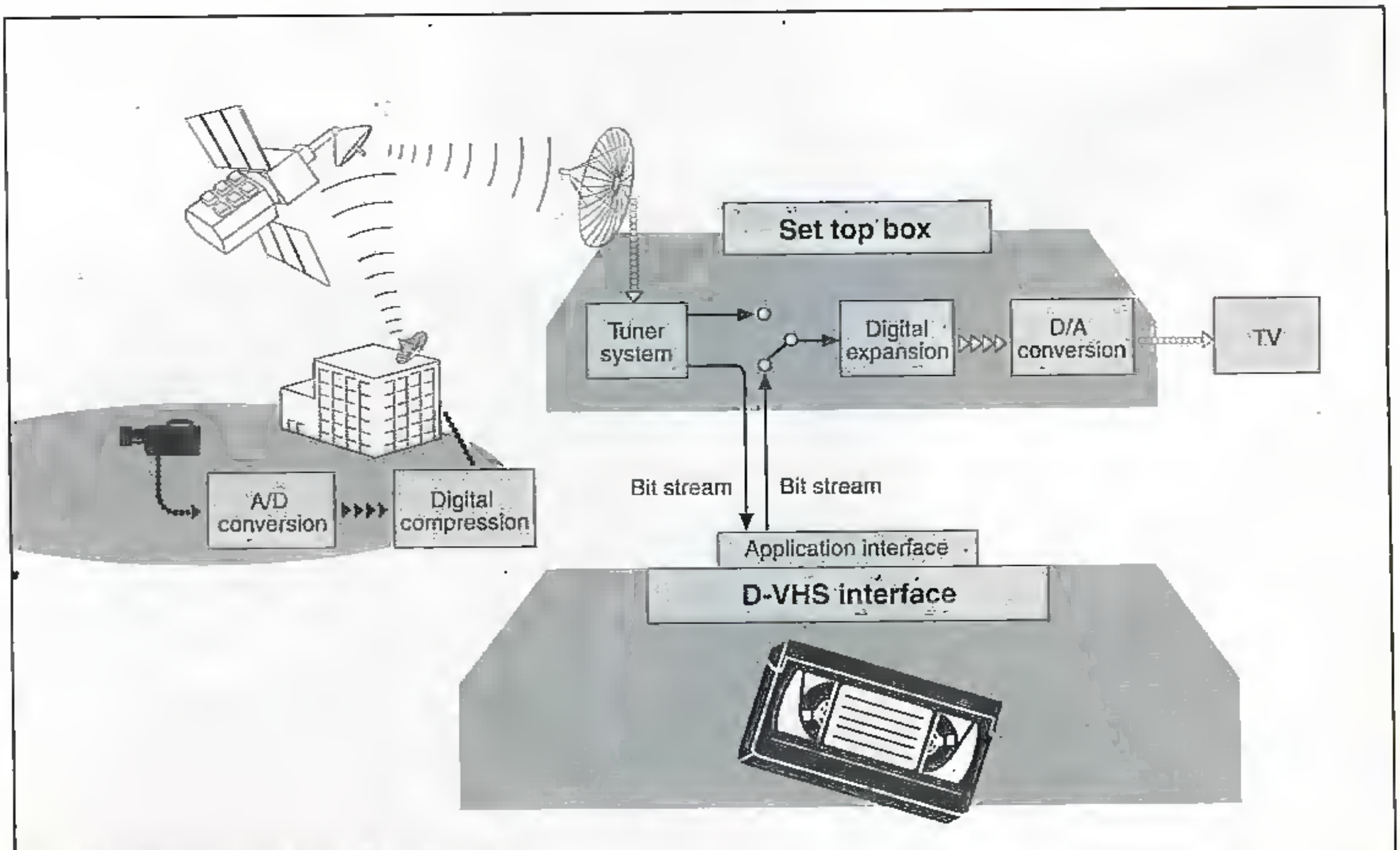


Figure 8. Digital broadcast recording with D-VHS.

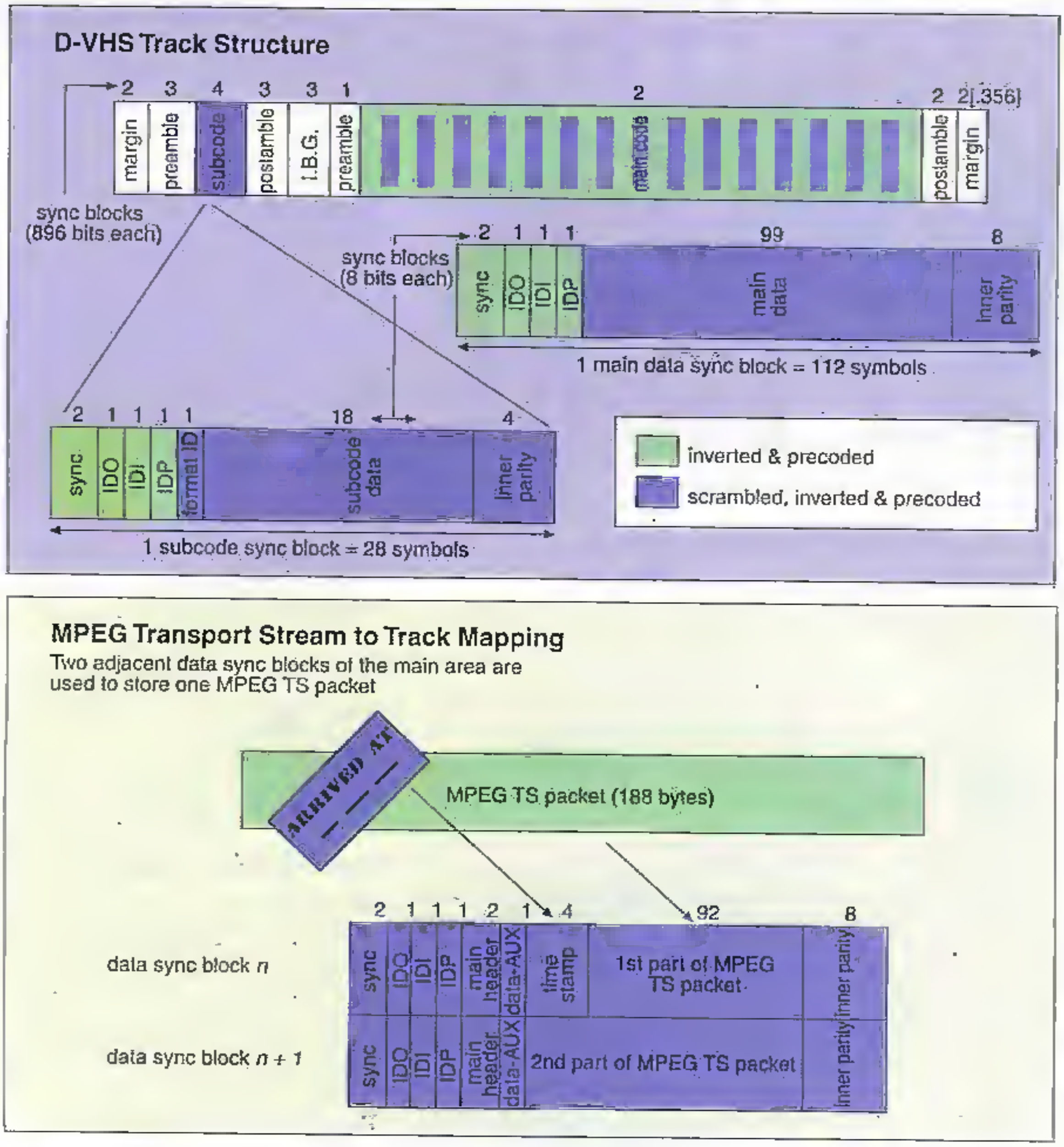


Figure 9. D-VHS track structure and MPEG Ts to track mapping. Courtesy of Philips

more audio channels, perhaps, or to mix aspect ratios, for as long as it is embedded in an MPEG-2 transport stream it is irrelevant to D-VHS.

D-VHS differs little from VHS. The track pitch is 29μm, the tape speed is 16.67mm/s, and the tape is an upgraded version of S-VHS oxide. Its recording data rate is 19.1Mbps, and its net data rate is 14.1Mbps (with bursts up to 72Mbps). The track structure and transport stream to track mapping are shown in Figure 9. In addition to this standard (STD) mode there is a high speed (HS) and four low speed (LS) modes for future products. These differ in tape speed and data rate. HS runs at double speed (33.33mm/s), with a net data rate of 28.2Mbps; LS2 runs at half speed (8.33mm/s), recording 7.0Mbps; LS3 runs at one third speed (5.67mm/s), recording 4.7Mbps; LS5 at one fifth (3.33mm/s) for 2.8Mbps; and LS7 at one seventh (2.38mm/s) for 2.0Mbps.

HS is intended for recording high definition transmissions - STD for the 625 line cable, satellite and terrestrial transmissions that can be received now, and multiple packages such as two or three movies broadcast simultaneously. LS will be for low bit rate broadcasting such as cartoons. A DF-300 tape that will give 3.6 hours in PAL SP VHS will give 5 hours in STD mode, while the DF-420 will give 5 and 7 hours respectively. So an on-screen menu will be provided for locating individual recordings.

Finally, the ATV and DVB variants of DV. It has gone very quiet... This could mean that an anouncement is imminent; or that they want to forget it. Personally, I cannot imagine many people wanting to buy a DV VCR for recording off-air, even if they have a DV camcorder, not when they will be able to buy a D-VHS one. But, time will tell.

Photo 6. Panasonic NV-DV10000 DV-VCR.

Signalling BY MEANS OF VISIBLE LIGHT

PART 2

In Part 2, George Pickworth Looks At Artificial Light & Light Beam Telephony.

Concurrent with advances in sunlight telegraphy, Clerk Maxwell predicted the existence of electromagnetic waves which were later demonstrated to exist by Hertz and are now generally referred to as Hertzian waves. However, any beliefs that Hertzian waves would quickly render landlines and cables obsolete were dispelled by Professor Thompson.

Thompson, experimenting with Hertzian waves about 1m long, demonstrated that they exhibited characteristics similar to light waves in that they could be reflected, refracted or diffracted. But of particular significance it was found that Hertzian waves, like light waves, are rectilinear.

Prof. Lodge believed that Hertzian wave systems would only have line of sight range and therefore could offer few, if any, practical advantages over visible light systems which included the heliograph, Aldis lamp and the Lime-light.

Direct

Faraday, around 1840, demonstrated that light is effected by magnetic fields, and when Hertzian waves were found to form part of the electromagnetic wave (em) spectrum, it was assumed that the only difference between Hertzian waves and light waves was their wavelength - see Figure 8.

Lodge believed that if a way could be devised to produce Hertzian waves with the wavelength of light, they would produce light far more efficiently than with incandescent lamp where much of the energy input is radiated as heat.

During his lecture to the Ashmolean Society at Oxford in 1898, Lodge expounded his philosophy that generation of light would be the most useful application for electromagnetic waves as it would have immediate and practical social benefits.

We now know that light has particle properties and this characteristic differentiates light from Hertzian waves, so direct production of light via Hertzian waves would seem to be impossible.

Difficult

Hertzian waves were, and still are, far more difficult to produce than light, moreover, a detector is required to make Hertzian waves manifest to human senses. On the other hand, visible light is detected directly by the eye. So, during the latter part of the 19th century it is not surprising that attention was more orientated towards improving communication systems based on light beams than towards Hertzian waves which were very much an unknown quantity.

Selenium

In 1870, an assistant of Willoughby Smith discovered that the resistance of selenium varied in inverse ratio to the intensity of applied light. This phenomenon, together with the development of the microphone and telephone earpiece by Professor Bell, provided the essential components for an amplitude-modulated, sunlight-telephony system. The heliograph provided a pattern for the vital sighting system

The Photophone

Working independently, Bell and AC Brown produced the first telephone to employ sunlight as the medium in 1881 and whilst generally known as the photophone, Bell seems to have called his version a radiophone - see Figure 9a.

Unlike contemporaneous inductively coupled telephones, where the sender and receiver were mutually coupled by their closed magnetic field, the photophone must go down in history as the first true radio telephone, i.e. where energy leaves the sender and is carried via waves to the receiver. There is no coupling between the sender and receiver.

Diaphragm

It will be seen from Figure 9a that parallel rays from the sun pass through a convex lens which causes them to converge on a small reflective diaphragm. After reflection,

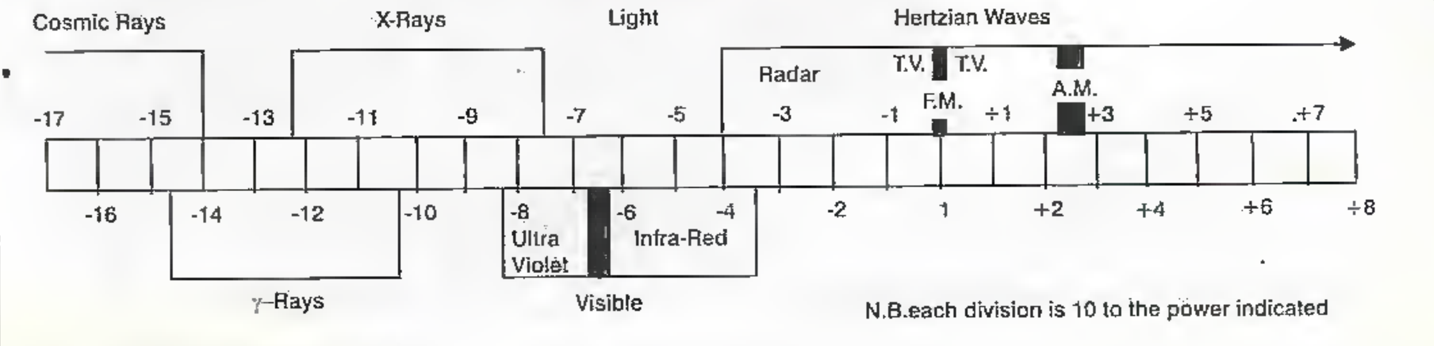
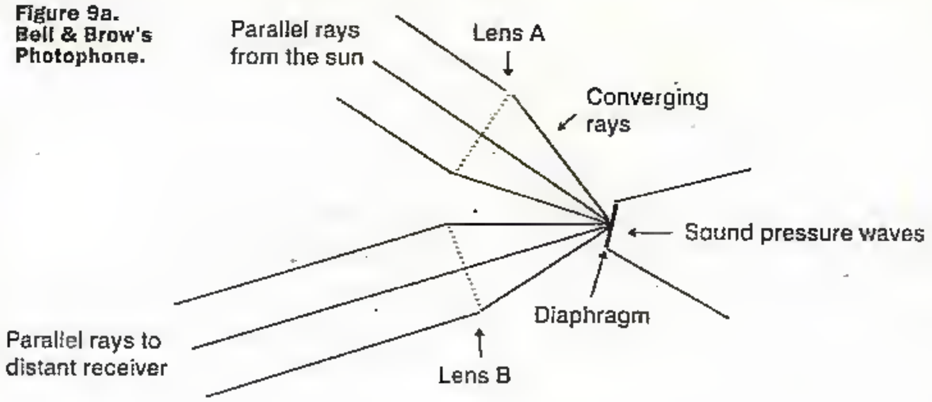


Figure 8. The electromagnetic spectrum.

Figure 9a. Bell & Brow's Photophone.



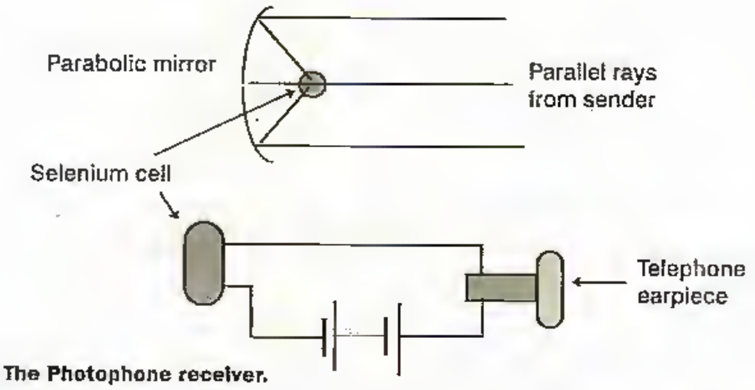


Figure 9b. The Photophone receiver.

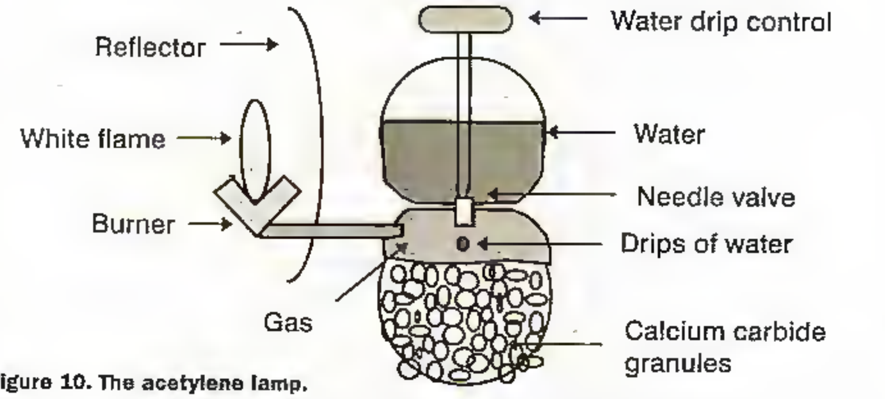


Figure 10. The acetylene lamp.

the rays diverge and are made parallel again by a second convex lens. The resultant pencil beam of light is directed to the distant station.

Directing the beam would have been simplified by using a mirror to direct the sun's rays on to the first lens of the modulator and a second mirror to direct the modulated beam to the distant station. The modulator could then have remained in a fixed position.

When the diaphragm was subjected to sound pressure waves, (shades of Edison's phonograph) it became alternately convex and concave to a degree depending on the magnitude of the sound pressure waves. This caused some rays to be reflected radially and therefore did not pass through the second lens. The effect was to amplitude modulate the reflected beam. Remarkably, a basically similar system was used with the German WW2 photophone, but more about that later.

Demodulation

The beam was demodulated at the distant station by means of a selenium cell and a telephone earpiece. Unfortunately I have no information of range attained. However, the upper frequency limit for a selenium cell was only a few hundred Hz but was apparently sufficient for intelligible speech - see Figure 9b

Artificial Light

Obviously, for signalling purposes, an artificial light source is far more versatile and convenient than sunlight. Moreover, with artificial light, the source is static and this avoids problems the movement of the sun.

The artificial light sources could either be integrated with the signalling system such as the Aldis lamp or as a light source for the heliograph during hours of darkness. Wick-type paraffin lamps were used during emergencies for short range signalling, but acetylene and lime-light lamps produced much more light - see Figures 10 & 11. Let us first look at the acetylene lamp.

Acetylene Lamp

Acetylene gas was produced in the lamp assembly by water dripping on to calcium carbide. A special burner produced an intense white flame. The lamp had two chambers, the upper containing water and the lower containing the 'carbide'. Water dripping on to the carbide was controlled by a needle valve - see Figure 10.

Carbide was produced by heating coke and limestone at a high temperature in a electric furnace. The lamp was environmentally friendly as the spent carbide was essentially lime and provided a useful garden fertiliser.

Acetylene lamps were universally used on bicycles and early cars. I had one on my bike, it gave a much brighter light than battery powered lamps and was much cheaper to run. Carbide was bought in sealed tins from general stores.

The Lime Light

The lime-light produced high intensity white light by heating a pencil of quick-lime (calcium oxide) in a flame rich in hydrogen and oxygen. With the circa 1900 signalling lime-light, the quick lime pencil was heated by a methylated spirit lamp complemented with a jet of oxygen. See Figure 11a. However, some types of lamps employed acetylene gas instead of methylated spirits.

The most remarkable feature of the signalling lime-light was the method of producing and storing the oxygen, for it was produced by boiling in water a mixture of potassium chlorate and magnesium binoxide in a retort placed on the camp fire. After passing through a cooler, the oxygen was stored in an animal skin bag held in a wooden frame. When oxygen was required for the lamp, a second bag filled with earth was placed on the storage bag, thereby pressurising the gas. See Figure 11b

Modulation

With sunlight telephony, i.e. the photophone, it was obviously only possible to modulate the light beam whereas with artificial light it possible to modulate either the light beam or the actual light source though the latter was generally only possible with an electrically generated light source.

Nonetheless, ingenious methods were tried to modulate acetylene gas lamps by inserting a gas bag, which also served as the diaphragm in the gas feed tube. The resultant pressure pulses caused variations in the intensity of the flame, see Figure 12. Let us now look at electrically generated light.

The Arc Lamp

Arc lamps powered by AC were notorious for generating sounds corresponding to the frequency of the supply current. This motivated Tesla to develop high frequency alternators so that the sound was above audibility. High frequency alternators were subsequently developed for use as Hertzian wave transmitters. On the other hand, an arc lamp fed with DC produced only a slight

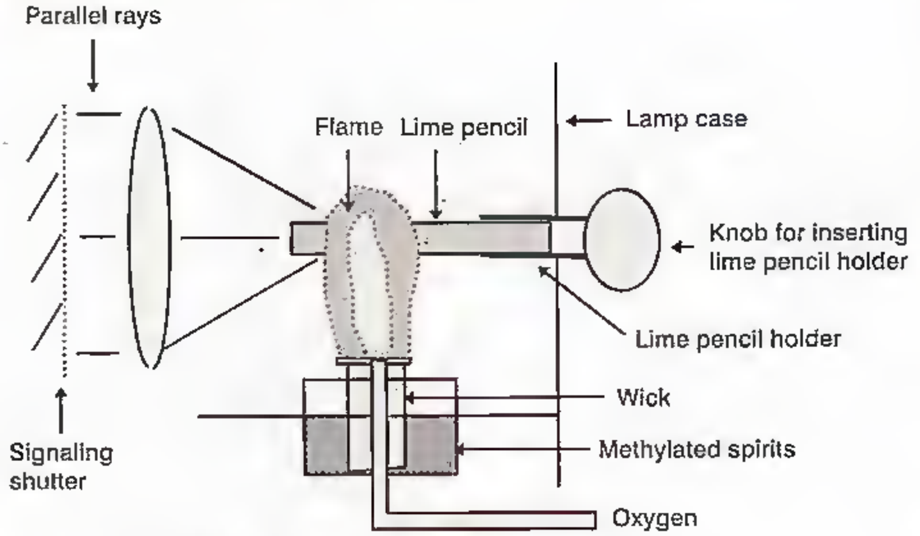


Figure 11a. Simplified diagram of a signalling lime light - the lime pencil is rendered white hot by the methylated spirit/oxygen flame.

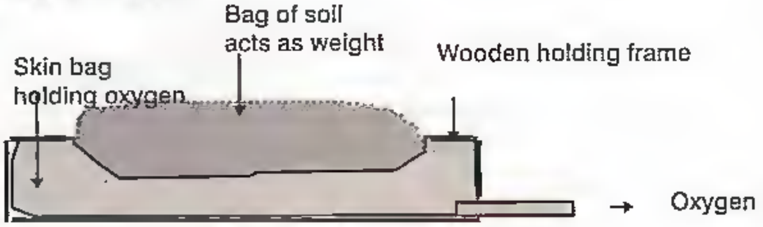


Figure 11b. Oxygen storage bag for lime-light.

'hissing' sound.

Around 1880 Prof. Ruhmer noticed that the audible sound corresponded to changes in the intensity of the light and the phenomena was attributed to variations in the volume of the plasma surrounding the arc - see Figure 13.

Speaking Arc

Ruhmer subsequently developed a method whereby the arc was driven by DC but modulated by pulsating DC produced by a microphone and battery - see Figure 13. The light beam was directed to the distant station where demodulation was by means of a selenium cell similar to that used with the photophone as shown in Figure 9. Range was given as 7km.

Enter The Thermionic Valve

The amplifying valve enormously increased receiver sensitivity but it also enabled electro/mechanical devices to be used to modulate the light beam. The most effective modulation method was to employ a solenoid, energised by speech currents, to partially rotate a mirror and thereby deflect some of the rays to where they were dissipated. The effect was that the intensity of the light beam varied in sympathy with speech. See Figure 14.

Power valves enabled electric lamps to be modulated directly, but this proved to be inefficient and was out of the question with early low power valves; these were best suited to amplifying receiver currents and as already mentioned for driving electro/mechanical modulators. Nonetheless, as more powerful valves became available, direct modulation offered an alternative to electro/mechanical modulators.

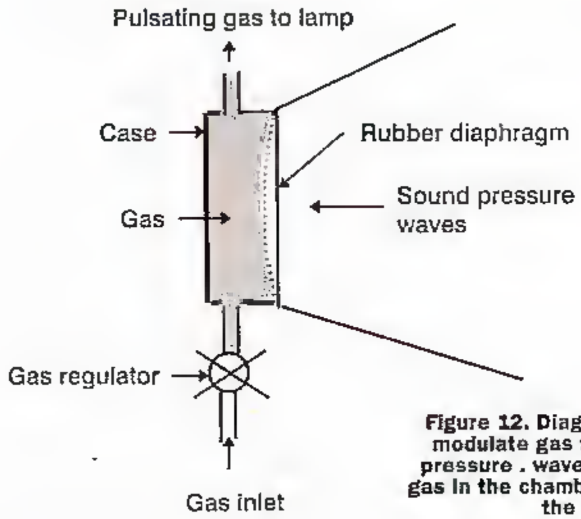


Figure 12. Diagram showing device to modulate gas feed to a lamp - sound pressure . waves acting on diaphragm gas in the chamber thereby modulating the gas . flow to the lamp.

Neon Lamp

Being a high voltage device, the neon lamp could be modulated when inserted in the anode circuit of a low power valve. With the valve operating in class A its quiescent current kept the lamp alight when modulation was zero. However, output from such a neon lamp was too low for light beam telephony.

The principle use of the neon lamp was to photographically record sound on cinema films by varying intensity of the light in sympathy with speech or music, this caused corresponding degrees of opacity on the photographic film. During projection, the variations in opacity caused a photo cell to produce electrical currents corresponding to the original sound.

Automotive Headlamp Bulbs

During the 1930's much interest was shown by experimenters in directly modulating automobile headlamp bulbs. Indeed, as a schoolboy, I too experimented with such a system in 1939 with the objective of establishing a light beam telephone link with my friend on Dost Hill. Unfortunately the war put a stop to my experiments but not before I had demonstrated the feasibility of the link. A simplified diagram of my 1939 system is shown in Figure 15a.

Because of the huge voltage difference, i.e. 300V to the 6L6 valve and 6V to the bulb, (many cars had 6V electrical systems in those days) transformer coupling was necessary. This arrangement had the advantage in that an auxiliary DC power source could be used to constantly bias the bulb to point where light emission varied more or less linearly to variations in modulation current. (As measured with a photograph exposure meter)

Because of the characteristics of an incandescent lamp, i.e. that resistance of the lamp increases in direct ratio to the temperature of the filament, light emission does not increase linearly with applied voltage.

My receiver, as shown in Figure 15b, had a viewing tube which enabled me to accurately focus light from the sender on to the photo cell. I am presently renewing my early experiments but using power FETs for modulation which nicely match with 12V automotive bulbs.

Electro/Mechanical

As already mentioned, much greater efficiency could be obtained by modulating the actual light beam by means of an electro/mechanical devices. the following WW2 apparatus being a good example. See Figure 16.

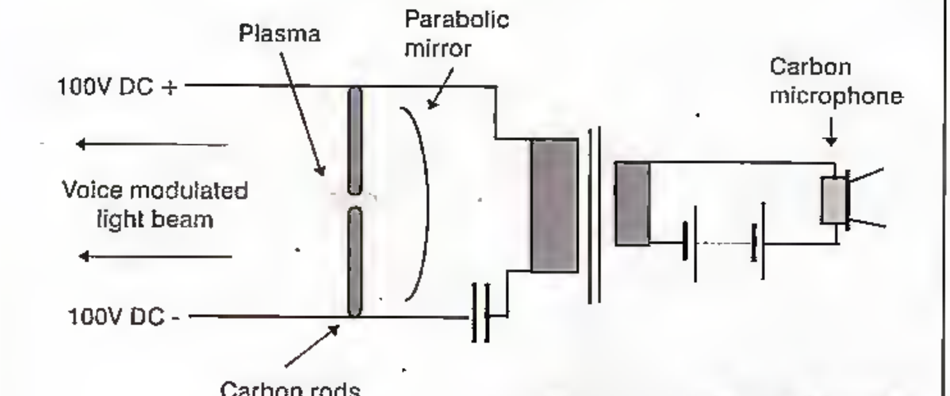


Figure 13. Ruhmer's 'Speaking' arc.

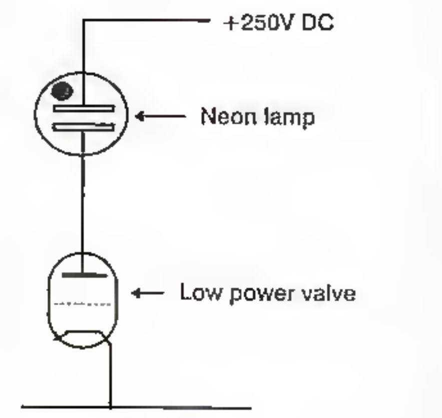


Figure 14. Direct modulation of a neon lamp - the valve's quiescent current keeps the . lamp alight when modulation is zero.

Although designed primarily for use with an electric lamp as the light source, the 1944 German Modulated Light Beam Apparatus (Photophone) Li.Spr 250/130 had an adaptor to enable the sun be used as the light source.

As the light could be interrupted and the device was used for visual telegraphy (Morse) I am not certain if sunlight could be modulated or if sunlight was used simply for telegraphy. Nonetheless, the modulator was basically similar to the original radiophone except that a small mirror rotated by a solenoid instead of a diaphragm. It also had polarisers which greatly improved the level of modulation.

Solenoid

My interpretation of how the device worked, taken from limited information available, is as follows. Microphone current was amplified by valves which energised a solenoid thus causing the mirror to rotate a degree or so in sympathy with speech. With no modulation, half of the light rays travelled through the space between the first polarised bars, and were therefore not polarised. The other half passed through the polariser bars and was therefore vertically polarised.

After being reflected from the mirror, the vertically polarised light travelled between the bars of the second polariser whilst the unpolarised light passed through the second polariser and therefore became horizontally polarised.

Modulation

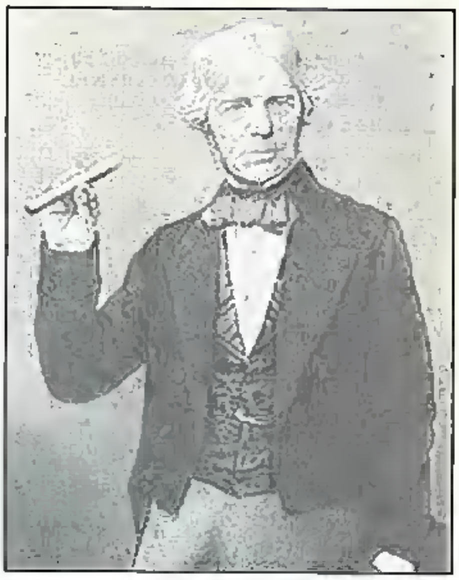
When the solenoid was energised, the mirror moved on its axis and the vertically polarised rays progressively came up against the second polariser where they were blocked. With maximum mirror movement, i.e. maximum modulation, emitted light was reduced by 50%. For night time telephony, red or infrared filters were brought into use - see Figure 16.

The receiver, installed in the same housing as the sender employed a photo cell and a three valve amplifier.

Modulation By Magnetic Field

The most elegant modulation system, though the least efficient, is based on the effect of a magnetic field on light. See Figure 17.

Light passes through the first polariser before entering the lead glass rod placed in the centre of solenoid. So, when the solenoid is not energised the light exits through the second polariser which is in the same plane as the first polariser.



When the coil is energised the magnetic field causes the light beam to twist within the glass rod and therefore become out of alignment with the exit polariser. The result is that the intensity of light exiting via the second polariser varies in sympathy with variations in the magnetic field.

As already mentioned, this effect was discovered by Faraday around 1830 but it was ahead of its time and had no practical application. However, electromagnetic modulation received renewed attention a few years ago, when it was found that the

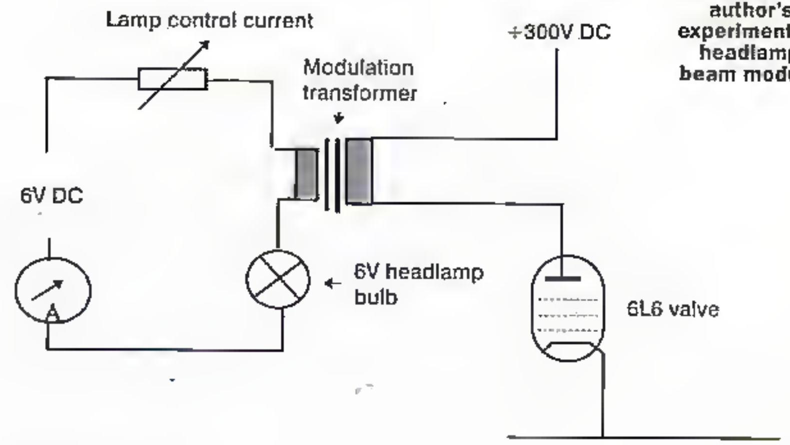


Figure 15a. The author's 1939 experimental car headlamp light beam modulator.

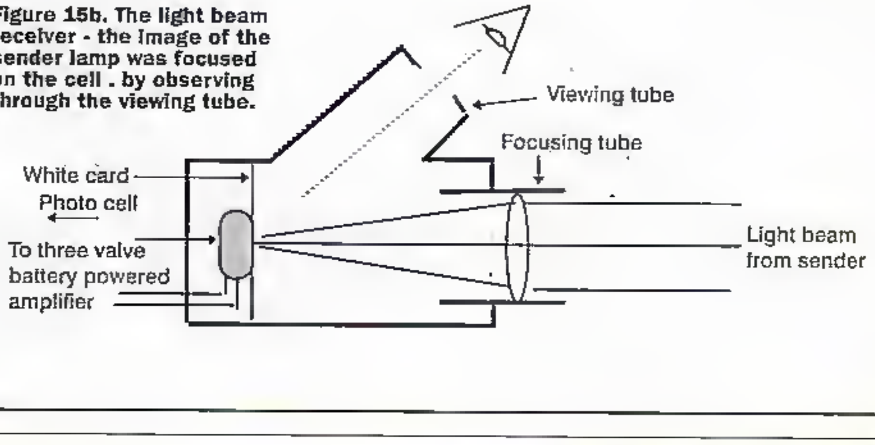


Figure 15b. The light beam receiver - the image of the sender lamp was focused on the cell . by observing through the viewing tube.

Figure 16a. German WW2 Photophone system Li. Spr.250/130 - No modulation. The output consists of both vertically and horizontally polarised light.

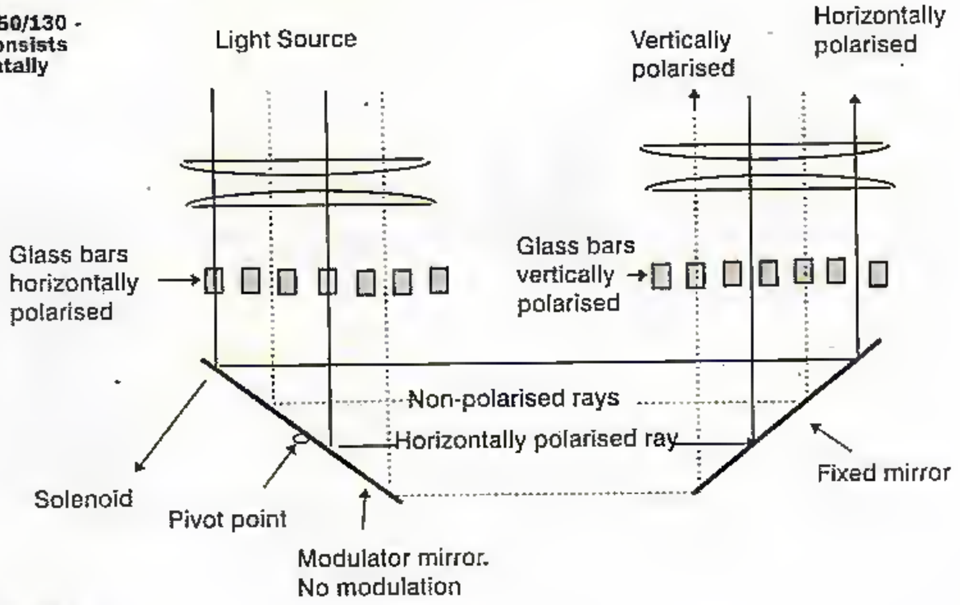
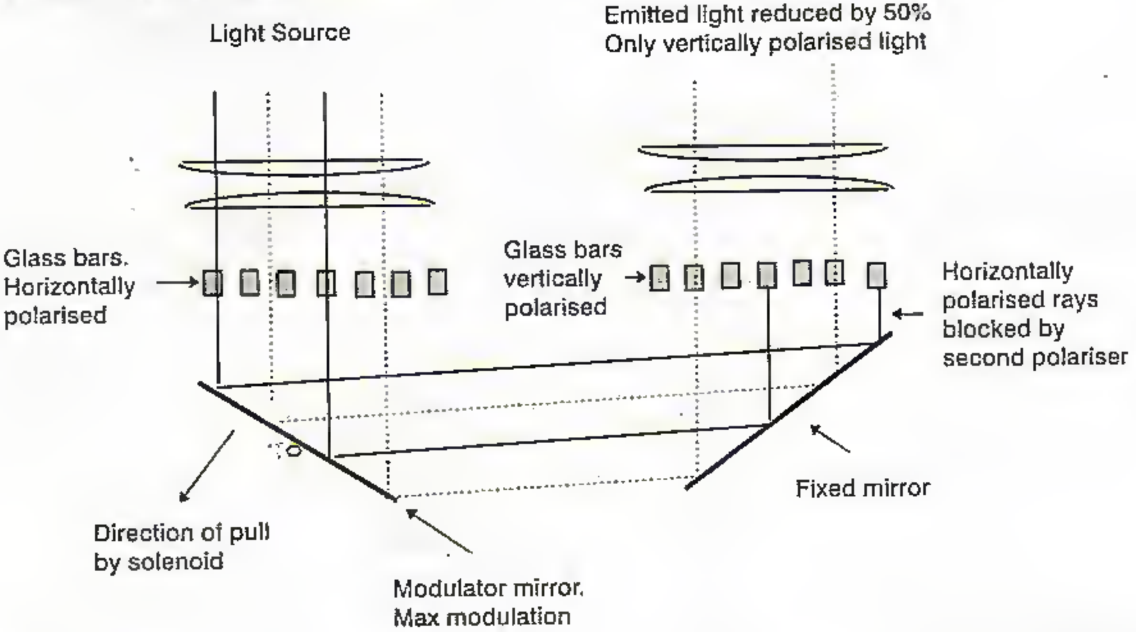

Light Source
Vertically polarised
Horizontally polarised
Glass bars horizontally polarised
Glass bars vertically polarised
Non-polarised rays
Horizontally polarised ray
Fixed mirror
Solenoid
Pivot point
Modulator mirror. No modulation

Figure 16b. With maximum modulation - modulator mirror now moved so that rays horizontally polarised by the first polariser are blocked by the second polariser. N.B. The rays actually converge on to a single very small mirror, in an arrangement similar to Figure 9a. Drawings are shown for clarity.


Light Source
Emitted light reduced by 50%
Only vertically polarised light
Glass bars. Horizontally polarised
Glass bars vertically polarised
Horizontally polarised rays blocked by second polariser
Fixed mirror
Direction of pull by solenoid
Modulator mirror. Max modulation

twist of the light beam was more pronounced when the lead glass rod was replaced by certain organic chemicals.

LEDs & Lasers

Even with modern light emitting diodes and lasers, modulation of the beam by electro/mechanical means still seems to offer many advantages for long range light beam telephony as the technique provides a simple method of modulating a very powerful light beam, which as we have seen, the source could well be the sun.

Obviously, inertia with any mechanical modulation system limits high frequency response and for that reason the mirror on the German WW2 photophone was made very small. However, electromagnetic modulation would seem to overcome the problems associated with electro/mechanical modulators.

In the final part of this study we will look at the future for sunlight signalling systems together with some thoughts on the story that the Greeks burnt the Persian ships at the battle of Salamis by soldiers reflecting sunlight from their shields.

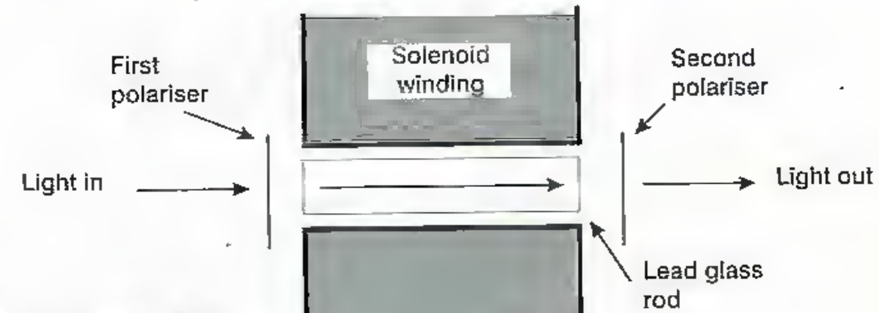
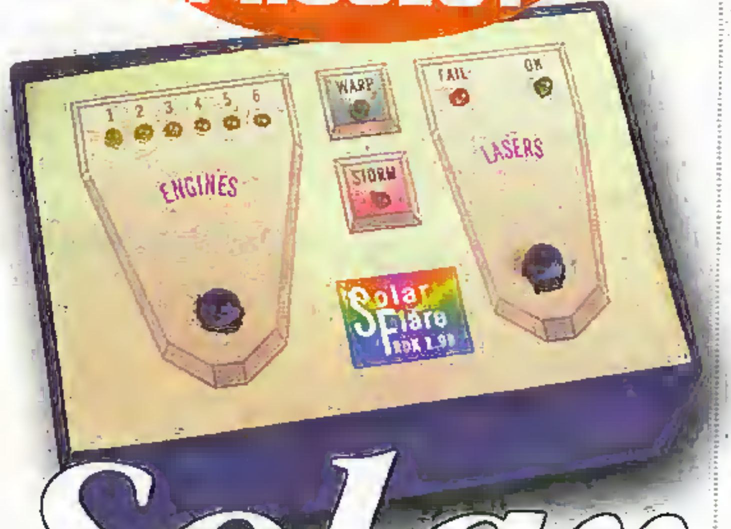


Figure 17. Modulation by electromagnetic field, based on Faraday's discovery.



Solar FLARE

Ray Kent describes a hybrid computer/ board game with a lot of excitement.

Introduction

Solar Flare is a cross between a traditional board game and a computer game. It has a playing board and pieces but moves are governed by a microcontroller module instead of the usual dice. The setting is somewhere out in space in the future. Your space-station's hydrogen tank has exploded and you must take on the dangerous mission of orbiting the nearest star to collect hydrogen before everyone on the station dies. You race against the other players to see who can complete the mission first. I made it for my eight year old nephew Gregory last Christmas and it went down well with him and the adults. It is mostly a game of chance but there are elements of risk taking and decision making which make it fun to play.

The heart of the game is an Atmel AVR 90S1200 microcontroller. It's a 20-pin RISC machine designed for very low component-count circuits. The S1200, as I'll call it for short, is electrically re-programmable which makes it great for experimenting. If you want to do this you'll need a programmer - there are a few types commercially available - and an assembler. Atmel has a free assembler available for download. If you just want to build this game then you can get a pre-programmed S1200 from the author, ready to plug in and play.

PICs With Everything?

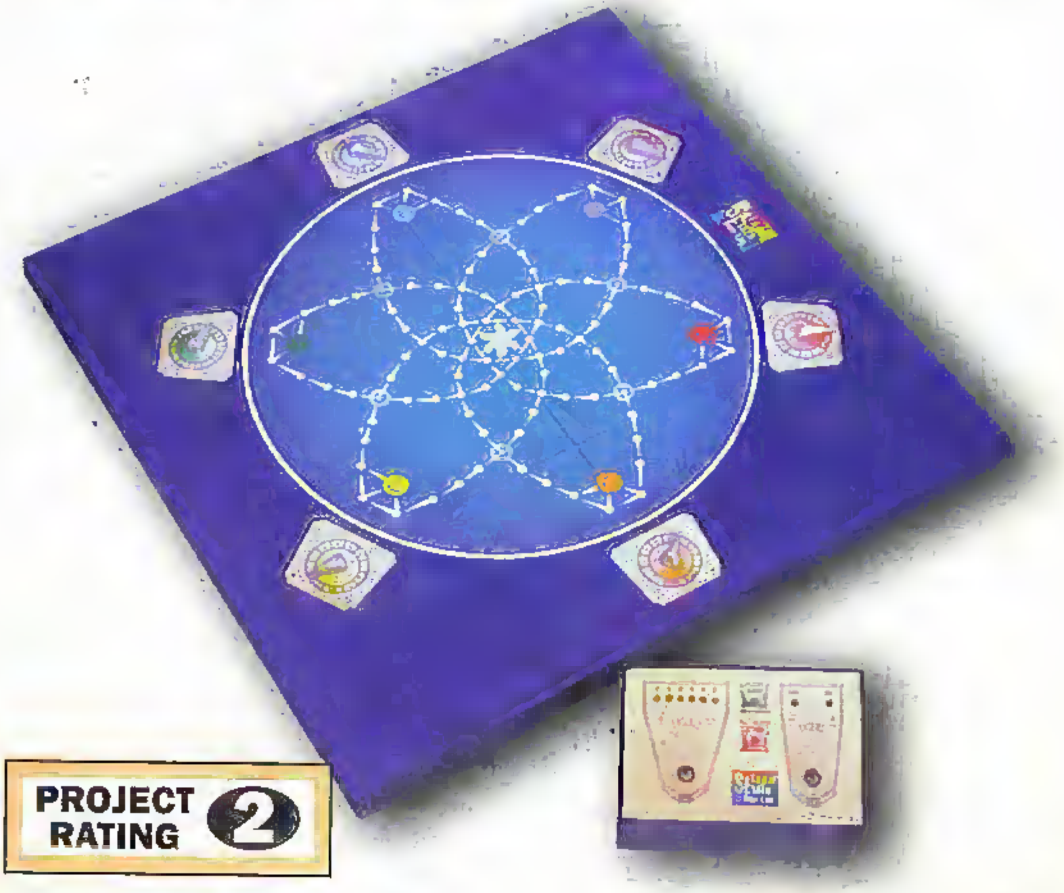
It used to be chips with everything, now it seems to be PICs with everything. At the risk of sounding like a Luton supporter, I have to say that I found that the range and diversity of the PIC family of microcontrollers gave me a headache - I became an AVR fan. A year ago the AVR family was simplicity itself: if your program was too big for the 90S1200 you put it in the 90S8515. A few more family members are available now, but these two chips will cope with a wide range of projects.

Getting It Wrong First Time

After 15 years of writing software I'm still incapable of getting a program right first time, so my first requirement for a microcontroller in a simple system is electrical re-programmability - ideally in-circuit. Build your circuit and if the program doesn't work click the erase button on your PC, amend the program, re-assemble it and squirt the new version into the chip down a serial link. The AVR is happy to do this up to 1,000 times before its FLASH memory gives up the ghost. Even I can usually get a small program right before version 1001.

Under the AVR's Hood

The family member used here is the AT90S1200. The S1200 has a Harvard architecture as opposed the more common Von Neumann architecture. Essentially this means it has fixed views on what's an instruction and what's a piece of data. Program instructions are held in 1Kbytes of FLASH which retains them during power-down and can only be modified with external support from a programmer circuit - either through a serial link or by the parallel method which involves removing the chip and placing it in a suitable programmer's ZIF socket. Data is held in two separate chunks of memory: one volatile, the



PROJECT RATING 2

other non-volatile. The volatile area is only 32 bytes in size and is described as 32 registers rather than RAM. The non-volatile area is 64 bytes of EEPROM which can be erased and re-written up to 100,000 times before it dies. This does not require any external circuitry - the chip has it all built in - your program can erase and re-write the internal EEPROM itself while running using very simple code. Just don't do it too often.

Having got used to working with PCs containing 32 Megabytes of RAM, the idea of dividing by a million (or so) and having only 32 bytes makes me feel rather claustrophobic, but this problem is remedied by other members of the family. If you need more RAM you could upgrade to the S8515 which has an extra 512 bytes as well as more pins and other features.

Go Slow

The S1200 can run at up to 16MHz using an external crystal and two capacitors, but if you're happy running at 1MHz you can dispense with these and use the on-chip RC oscillator. The faster it runs the more current it consumes and the faster the battery dies. Solar Flare runs at 1MHz and just about manages to construct simple audio square-waves and noise at a 10kHz sample rate. The processor consumes a miserly 3mA when fully active in this application.

Not Sourcing, But Sinking

The S1200 has 15 programmable I/O lines. Each port (pin) of the S1200 can sink 20mA, but will only source about 2mA. This means you can drive an LED directly (via a current limiting resistor) in sink mode.

A Passing Mention

I'll briefly mention some other highlights of the S1200's specification

- RISC design - most instructions execute in a single cycle
- Versions are available for supplies between 2.7V and 6V
- 8-bit timer and pre-scaler
- External and internal interrupt sources
- Programmable watchdog
- Analog comparator
- Low power idle and power-down modes
- Software security lock
- Programmable pull-up resistors for unused or input ports - nice one. I once designed a circuit for an 80-pin microcontroller where most of the board was filled with useless but necessary resistors.

An important non-feature is that you can't add external program memory (since it will only fetch instructions from internal Flash). Adding external data memory would be just about possible in a Heath-Robinson kind of way.

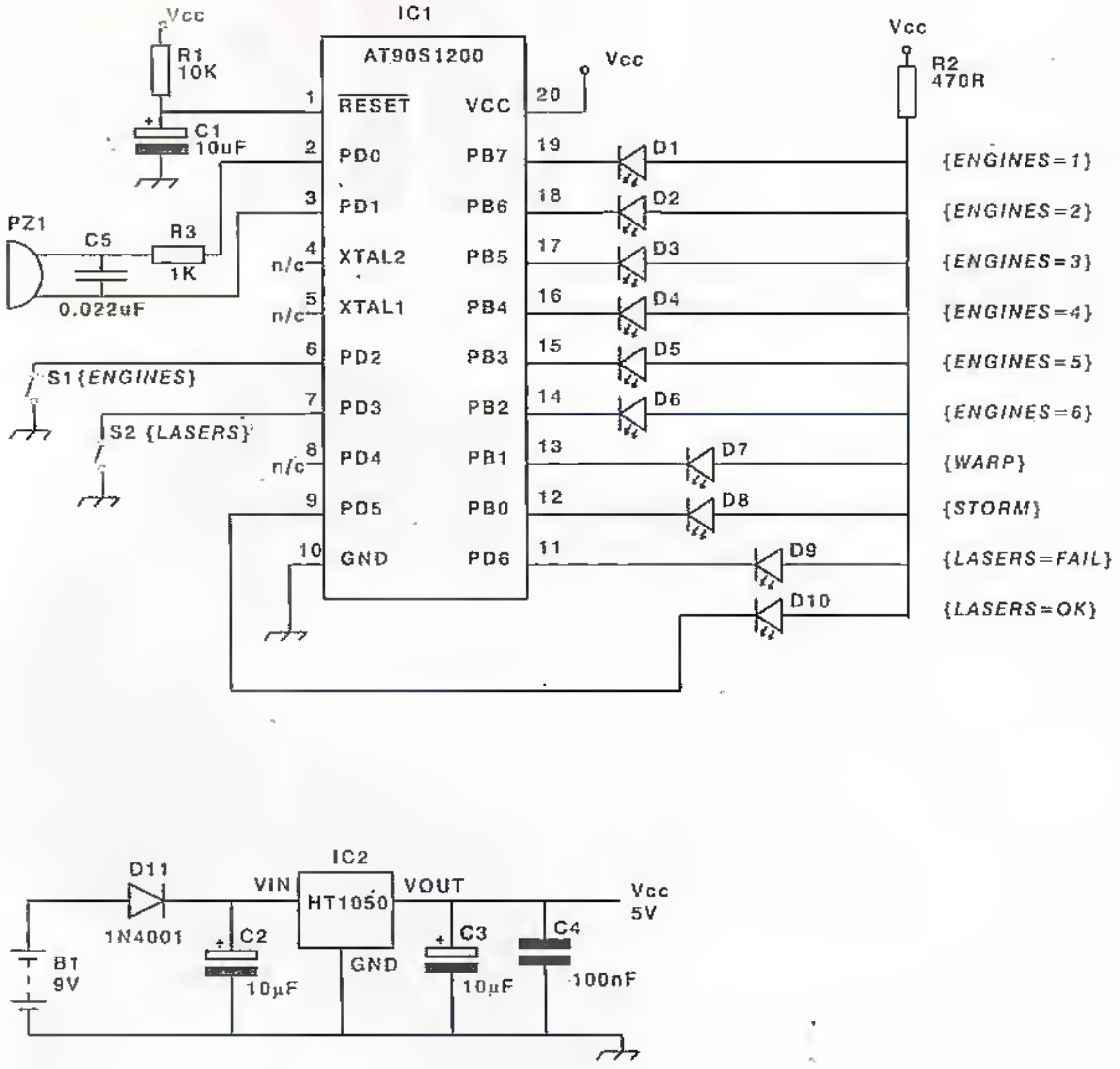


Figure 1. Complete circuit for 'Solar Flare'.

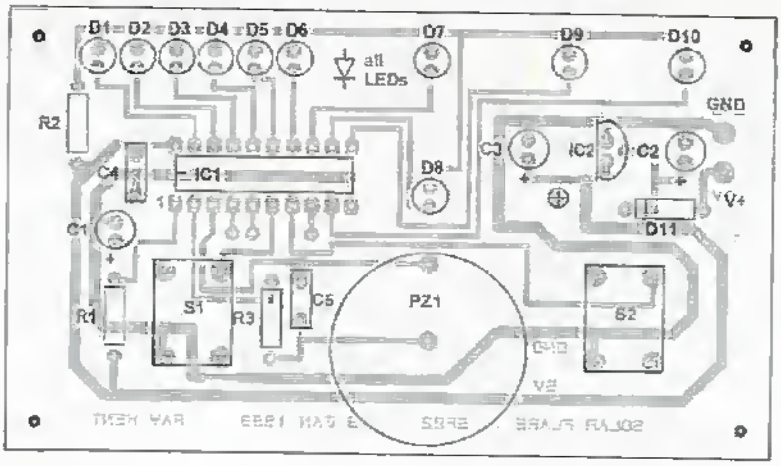


Figure 2. Component positioning.

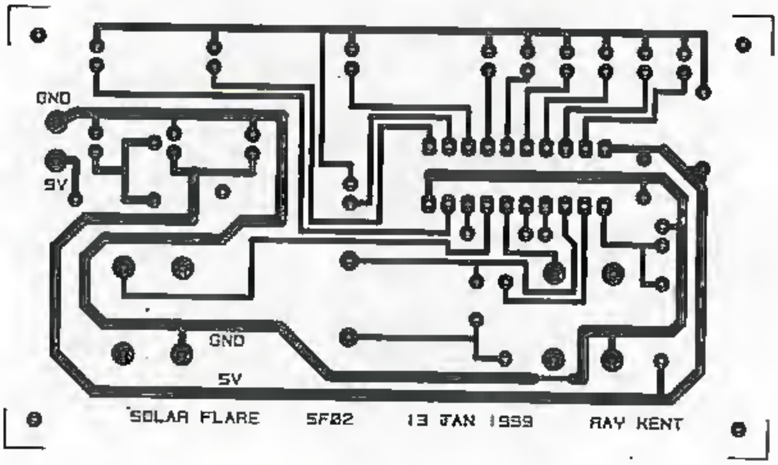


Figure 3. PCB track layout.

Circuit Description

The 9V PP3 battery is connected via polarity-protection diode D11 to a standard regulator circuit based around IC2, C2 and C3. This is a low-drop regulator with a low internal current consumption of 3.5µA. C4 is fitted close to the microcontroller (IC1) and provides supply-line de-coupling. When power is applied, pin 1 of IC1 is held low keeping it in RESET state until C1 charges via R1. The microcontroller then comes out of RESET state and starts program execution.

LED Outputs. Each port line of IC1 is configurable as input or output. Here, we set all 8-Port B lines and lines D6 and D5 to output. These 10-lines can turn the LED's on by being set to zero, sinking current. The LED's share a single current-limiting resistor in this design, which means they will be slightly dimmer if more than one is on concurrently. In practice, the software only drives one LED at a time except during the 'Warp' condition (two LEDs) and the start-up routine (three) and it's not noticeable.

Inputs:

Ports D2 and D3 are connected via S1 (the 'ENGINES' button) and S2 (the 'LASERS' button) respectively to ground. These two lines are programmed as inputs with the internal pull-up resistors activated, so they will be at Vcc except when a button is pressed.

Sounds:

The piezo sounder PZ1 provides simple sound effects. Ports D0 and D1 are driven in push-pull mode - when D0 is high D1 is low and vice versa. A bit of 'top' is filtered off the signal by R3/C5. Make sure you use a 'sounder' or bare transducer, not a piezo buzzer. Buzzers have a built-in oscillator circuit and only produce a single tone. The piezo produces a rather thin sound, particularly if you try a bare transducer element - the casing of a 'sounder' makes a big difference. If you like to experiment, try attaching a bare transducer to the base of a thin plastic disposable cup (you'll need a bigger case). Or go the whole hog and replace the piezo by a simple audio amp and speaker (but don't connect Port D0 directly to your hi-fi - it won't like a 5V signal with a strong 10kHz component!).

Unused Pins:

Port D4 is unused. Lines XTAL1 and XTAL2 could be connected to a crystal circuit to provide a higher clock-speed (up to 16 MHz), but in this design we use the internal 1MHz RC clock so they are left unconnected.

Battery Power.

There is no on/off switch. The software puts the S1200 to sleep after four minutes of inactivity or when the user presses both S1 and S2 together. Pressing S1 generates an interrupt to wake it up again. The circuit consumes about 10mA when fully active and a negligible 5µA when sleeping. Don't waste your money on exotic batteries for this circuit - the cheapest variety of PP3 will probably last for more than a year in the hands of anyone other than an obsessive enthusiast.

Software Description

This is not the place to give a crash-course in AVR assembly language, so I will just give an outline description of the functionality.

Reset:

After powering up, the chip leaves RESET mode and starts program execution. We initialise the ports by setting them up as input or output. We activate the pull-ups on the two input switch lines, and for the output ports, set their initial state to 'one', which puts them at 5V and therefore turns all LEDs off. Note the inverse logic - zero for LED on, 'one' for LED off.

We initialise the timer to provide interrupts at 100µs intervals - i.e. a frequency of 10kHz. Since most of the instructions are single-cycle we might hope to execute up to 100 instructions between interrupts. Much of this capacity is taken up by the interrupt service routine itself. If you try adding much code to this routine you can expect bizarre behaviour as the main routine may never get time to execute.

Welcome:

The start-up routine now provides a son-et-lumiere show with LED's flickering on and off to the accompaniment of a hissing sound. After a short time it goes quiet and alternates Warp and Storm LEDs, waiting for input.

Timer:

The Timer ISR (interrupt service routine) is the heart of the program and does a number of jobs.

1. Maintain a software clock (Xtim) to provide an easy way for other routines to achieve delays.

2. Maintain an EXOR random number generator which continuously generates 24-bit numbers.
3. Output 'samples' to the piezo according to the value of the control byte 'Audio' to generate noise or waveforms of two different pitches.

Main Loop:

The program's main loop monitors the state of the two buttons. When a button is pressed it sets the audio-control variable to request the 'key-click' sound - a short noise burst. If the player holds the button down the code keeps repeating the click until they release it. The routines for the ENGINES and FIRE buttons are very similar. Next they set the audio-control variable to the ENGINES or FIRE sound, as appropriate. After a short interval they determine the outcome by referring to different sections of the 24-bit random number currently in the random-number generator. When the outcome has been decided an appropriate sound-effect is triggered and the result displayed on the LEDs.

Pressing the ENGINES button will light a single engine LED or, less commonly, the STORM LED. If an engine LED is lit then the WARP LED may also be lit - signifying an extra go. The laser LEDs will be off. Pressing the LASER button will result in either OK or FAIL being lit, with OK being more probable than FAIL; all other LEDs will be off.

Sleep:

If no buttons are pressed for four minutes or if the user presses both buttons together the software will put the S1200 into power-down mode. Before it executes the sleep instruction it ensures that the ENGINES button has been released and then enables external interrupts on this button. To wake the system up the user presses ENGINES, calling the external interrupt ISR which disables external interrupts so we don't get any during normal running.

Construction Of The Electronic Module

With only 25 components, this is pretty straightforward. The main thing to watch out for is the height of components above the PCB - if the top panel is raised any further you would need taller switches. The easiest way to get the LEDs to the right height is to cut two strips of cardboard 0.25in. wide for stand-offs - a long strip for the top row of LEDs and a short strip for the STORM LED. Glue these to the PCB to run between the LEDs legs. Get the LED polarity right - the longer lead goes to the common line, the shorter lead goes to the S1200.

It's safest to put IC1 in a socket but it must be very low-profile to fit. I cut two lengths of ten from a socket strip for this. The top end of IC1 (marked with a dot or cut-out) is to the left when you view the PCB from above in the normal playing position - i.e. switches near to you, LEDs away from you.

I used low-profile radial electrolytics for C1, C2 and C3 but if you use taller ones there should be room to bend the leads and mount them horizontally. Bending C4 over gives easier access for inserting and removing IC1.

IC2 has three leads in-line at a spacing of 0.05in. This is uncomfortably close for DIY PCBs so I have moved the centre pad out of line - you'll need to bend the centre lead to fit. This component can also be fitted horizontally.

The leads from the PP3 clip pass through a small hole in the PCB where they can be locked with a spot of glue.

If you use a bare piezo transducer instead of the sounder recommended then bear in mind that it will be very quiet unless you make a small enclosure for it. This is pretty easy to do with thin plastic and glue.

I made a case out of 2mm MDF but the job was far too fiddly to describe here. The Maplin PB1 box is a close fit but you will need to trim down the pillars and mount the PCB with some well-placed filler. A bigger box would give more breathing space and might make construction easier, and watch out for clearance on the PP3 holder - some types of holder are a lot bigger than the PP3 itself.

Construction Of The Board & Playing Pieces

There are lots of options here depending on your artistic skills and how smart you want the result to look.

The published drawing of the board is reduced in size. Ideally it should be blown up onto A2, but A2 colour copies can cost £20 each. You could photocopy it at a lower magnification onto A3 paper. Alternatively you could opt for the portable chess-set type of approach using pegged pieces on a small playing board. Seal a sheet of 2mm or 4mm MDF by painting it on both sides to prevent warping. Use white paint (e.g. household emulsion) because strong colours will show through the paper to some extent. Glue the photocopy onto it - spray adhesive is pricey but worth it in my opinion. If the copy is black-and-white then colour it in with thin artist's acrylic paint and a very small brush - alternatively watercolour or colouring pencils might do. You only really need to colour the space-stations and it is best to leave the background in black and white unless you're good at getting even transparent washes. Protect the surface with a varnish that doesn't cause the colours to run - test on a piece of scrap before ruining your artwork!

Various modelling clays and putties are available for hand-sculpting the shuttles and gauge pointers - it's not difficult. Milliput and Fimo are two of the options, but for a ready-made solution you could use a cork pin-board for the playing board and coloured plastic-headed pins for the pieces.

I made gauge pointers by forming modelling putty around the head of an M3 bolt which is then passed through a hole in the board and secured with washers and a self-locking nut.

If you want a really professional finish and see all that as a hassle rather than an opportunity to exercise your artistry then I can supply a colour-printed A2 sheet for the board and cast plastic shuttles and pointers.

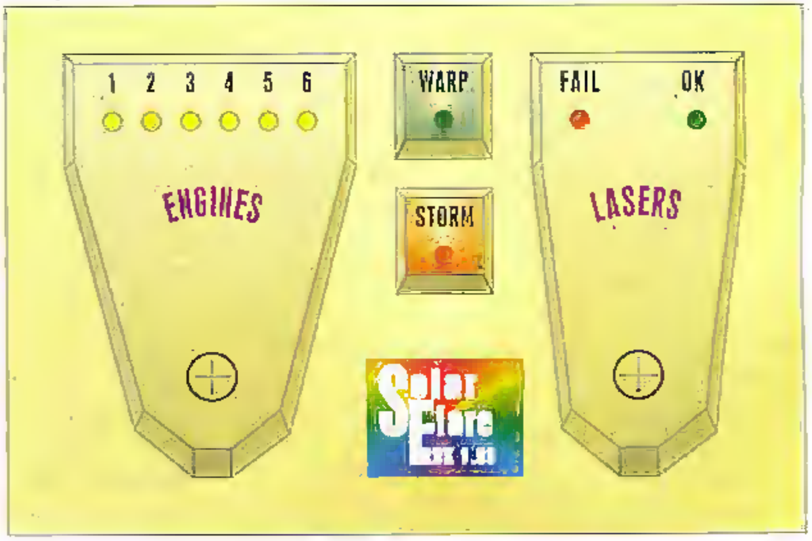
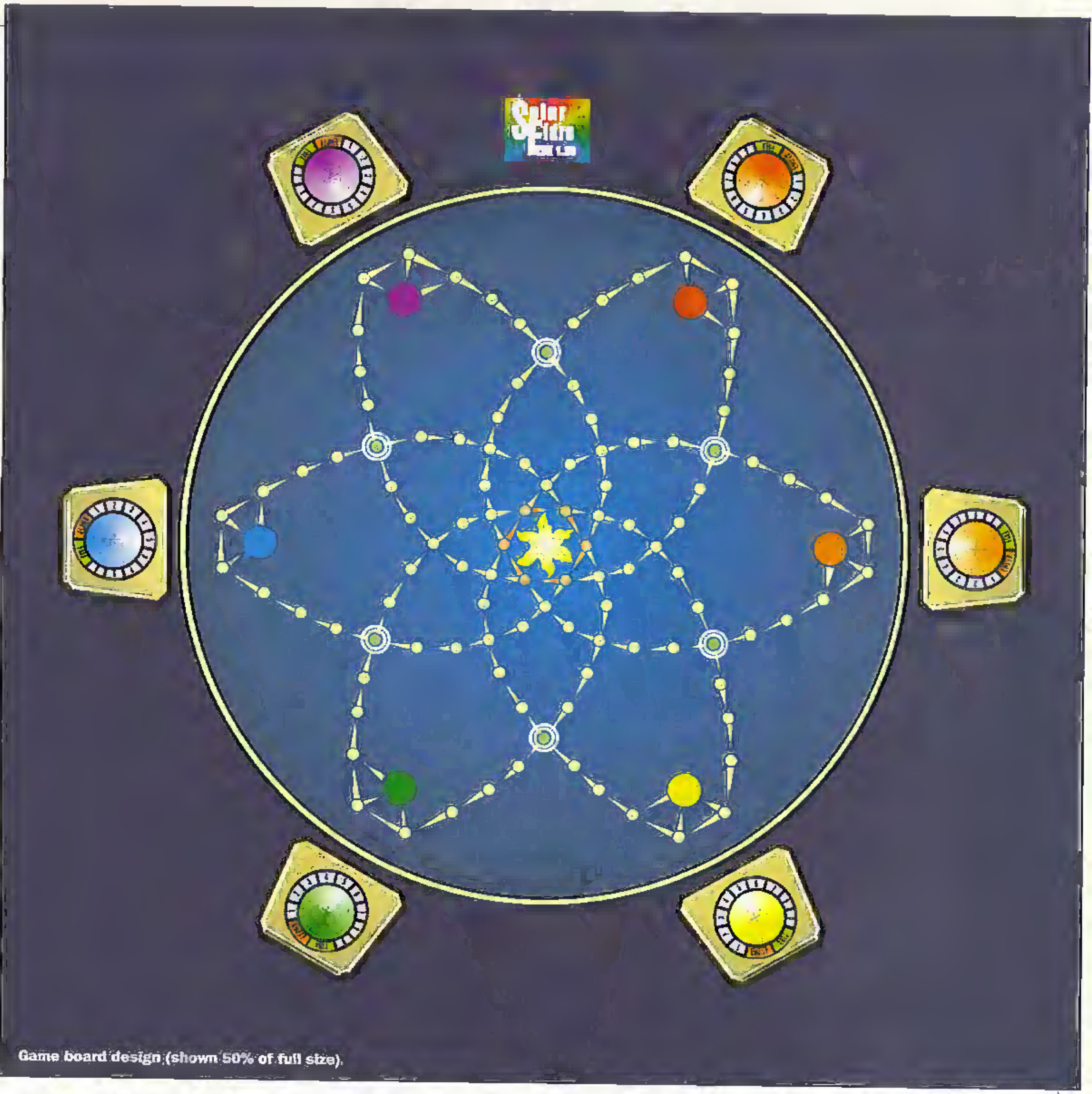


Figure 4. Box template showing LEDs.



Game board design (shown 50% of full size).

Solar Flare Rules

Your Mission

Your space-station's hydrogen tank exploded yesterday. Without hydrogen you can't make water and the water stocks will only last a few days. Even the emergency supply ship can't reach you in time. You hit on a brilliant idea: the enormous flares bursting miles out into space from the nearest star are made mainly of hydrogen - you could take a shuttle and collect some. It's insanely dangerous but it's the only chance for everyone on the space-station. Your mission is to collect a tank full of hydrogen and bring it back.

The hydrogen has to be collected by travelling around the inner orbit, closest to the star. It's marked in red. Each step along the inner orbit gains you one unit of hydrogen. Unfortunately, this is a very dangerous region - at any moment a solar storm could erupt, flinging you out of orbit, or you might be attacked by other players lasers...

Choose Your Station

Each player selects a space-station (the six coloured circles toward the edge of the board) and places a shuttle of the same colour on it.

Who Goes First

Going clockwise around the board, the colours are in the order of the rainbow - 1:red, 2:orange, 3:yellow, 4:green, 5:blue, 6:violet. Repeatedly press ENGINES until somebody's number comes up - this player has the first turn.

Taking it in Turns

Players take turns according to the order of the space-stations, going clockwise around the board, i.e. blue goes after green, etc.

One-Way Streets

The line connecting any two neighbouring points is a 'one-way street.' You can only travel in the direction of the arrow - from the thick end to the point. If you study the board you'll see that this simply means you can only travel clockwise, never anti-clockwise.

Junctions

Some points have two paths leading out of them. You can take either path. You can change direction in this way during a move.

Exactly - or Minus One

When it is your turn you press the ENGINES button. It will normally give a number from one to six. You can choose the number shown or that number minus one. So if it shows '5' you can choose '5' or '4'; if it shows '1' you can choose '1' or '0', etc. Occasionally it shows STORM and no number - you don't get a move.

You must move if there is a path available from the position you're starting in - even if it is not in the direction you would like to go. If you are completely blocked by other shuttles you must move as far as possible.

No Jumping

You cannot jump over another shuttle in a normal move.

Collecting Hydrogen

You collect one unit of hydrogen for each step you make along the INNER ORBIT, i.e. between two points that are both on the INNER ORBIT. (You don't collect a point for arriving on the INNER ORBIT or leaving it - only when you're travelling along a red path.) You cannot collect hydrogen during a move that makes a laser challenge (see later).

Inner Orbit Speed Limit

The INNER ORBIT is a tight curve and you can't stay in it with a speed above three. So in a single move you cannot move more than three steps along the INNER ORBIT. For example, if you are on the INNER ORBIT and you get a four you could choose to move three (the 'Minus One' rule) or you could move three on the INNER ORBIT and then leave it for the last step.

Time Warps

When you press ENGINES you may get WARP lit up in addition to a number. This means you are in a time-warp and can make an extra move before the next player's turn. Make your first move (dealing with hydrogen collection and any challenge you might make). Then say whether you want to make a second move. If you decide to make a second move press ENGINES again and make the move in the usual way. You cannot change your mind after pressing ENGINES - you must go ahead with the move.

When you press ENGINES for your second move you might be really lucky and get WARP again, in which case you can have a third move, and so on.

Each time you press ENGINES it is a separate move. This is important for the INNER ORBIT speed restriction and laser challenges where certain restrictions apply to a move, not to your whole turn.

Laser Challenges

If your move will take you to another shuttle's position (not past it) then you must challenge that shuttle to a laser battle, since two craft cannot occupy the same position. You cannot collect hydrogen during a move that makes a challenge.

Move your shuttle to the position one short of the shuttle you are challenging. Tell the other shuttle that you are making a challenge and press the LASERS button. If it shows OK you win, if it shows FAIL you lose. The two results aren't equally likely - you normally win.

Move the losing shuttle to the nearest vacant SAFE POSITION - that is the one that can be reached by the shortest orbital path from its present position. Ignore the 'No Jumping' rule. (There are six SAFE POSITIONs - marked with rings.) If the shuttle making the challenge won move it one step to the position that was challenged.

Neither shuttle can collect hydrogen during this whole sequence.

It's not always a good idea to challenge another shuttle if you could avoid it by moving less, for example. This is especially true if the other shuttle is on its way home - you might help it along its way!

Solar Storms

When you press ENGINES it may not produce a number but light up STORM instead. The STORM affects ALL shuttles that are currently on the INNER ORBIT. Starting with yourself, and working clockwise around the players, each shuttle on the INNER ORBIT is flung out to the nearest vacant SAFE POSITION, ignoring the 'No Jumping' rule (just as if it had lost a laser challenge). Any shuttles that are not on the INNER ORBIT are not affected. Play then passes to the next player.

Tank Full

When your hydrogen tank is full you can start making your way back to your space-station. The tank cannot get overfilled - you can still travel along the INNER ORBIT and just ignore additional hydrogen units.

Docking

To finish you must dock with your space-station (getting your shuttle back to the marker it started on). You can't dock if you're travelling too fast, you overshoot. The space-station has two entry points. This, combined with the 'Minus One' rule means that you have about a fifty-fifty chance of getting on to it when you approach. If the number given by ENGINES is too high then your shuttle overshoots around the back of the space-station and will have to orbit the star again.

The first shuttle to dock is the winner. Good Luck!

PROJECT PARTS LIST

RESISTORS			
R1	10k Min Res	1	M10K
R2	470 Min Res	1	M470R
R3	1k Min Res	1	M1K
CAPACITORS			
C1,2,3	GenElect 10µF 16V	3	AT98G
C4	0.1µF MiniEster	1	CX21X
C5	0.022µF MiniEster	1	CX19V
SEMICONDUCTORS			
IC1	AT90S1200/16PC	1	NR25C
IC2	Voltage Reg HT1050	1	BH68Y
D1,2,3,4, 5,6	Mini LED Yellow	6	YY38R
D7,10	Mini LED Green	2	WL33L
D8,9	Mini LED Red	2	WL32K
D11	1N4001	1	QL73Q
MISCELLANEOUS			
S1,2	Lo Profile Sw HiButn	2	CL48C * or CL49D plus CL52G for taller button
PZ1	PCB Piezo Sounder	1	JH24B
	32 Socket Strip	1	DC17T
	PP3 Batt Box	1	CK65V
	PP3 Clip	1	HF28F
	Zinc Chloride PP3	1	NC97F
	Box PB1 Black	1	LH14Q * see text
	PCB	1	* see text
	Playing board	1	* see text
	Shuttles	6	* see text
	Gauge pointers	6	* see text

THE AUTHOR CAN OFFER THE FOLLOWING PARTS:

Drilled fibreglass PCB	£6.50
Pre-programmed S1200	£7.50
A2 colour sheet of board and control-panel	£6.00
Set of 6 playing pieces and 6 gauge-pointers	£4.50
All 4 of the above items as a set (saving £2)	£22.50
Or, for the more DIY inclined:	
Software and drawings on floppy-disk	£4.00

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Mighty MACHINES

Gregg Grant recalls some of the glorious machines of yesteryear.

Introduction

Not the least of nature's ironies is that, in order to investigate the behaviour of the smallest particles, scientists have to use some of the largest pieces of kit yet devised by man. Such machines - to the layman at least - appear to have names, acronyms and initials as obscure as their functions.

To the Victorians, machines were *the* symbol of their technological virility, as well as demonstrating the progress that science and its application had brought, and would continue to bring. All that was needed was more - and bigger - machines. Therefore when they built machinery they built big, and built to last. This is still evident today when, in a number of areas, machinery of Victorian vintage is being replaced. So solid were many of those structures that - even with modern demolition techniques - they are by no means easy to remove. A good example of a Victorian electrical device was the Wimshurst Machine.

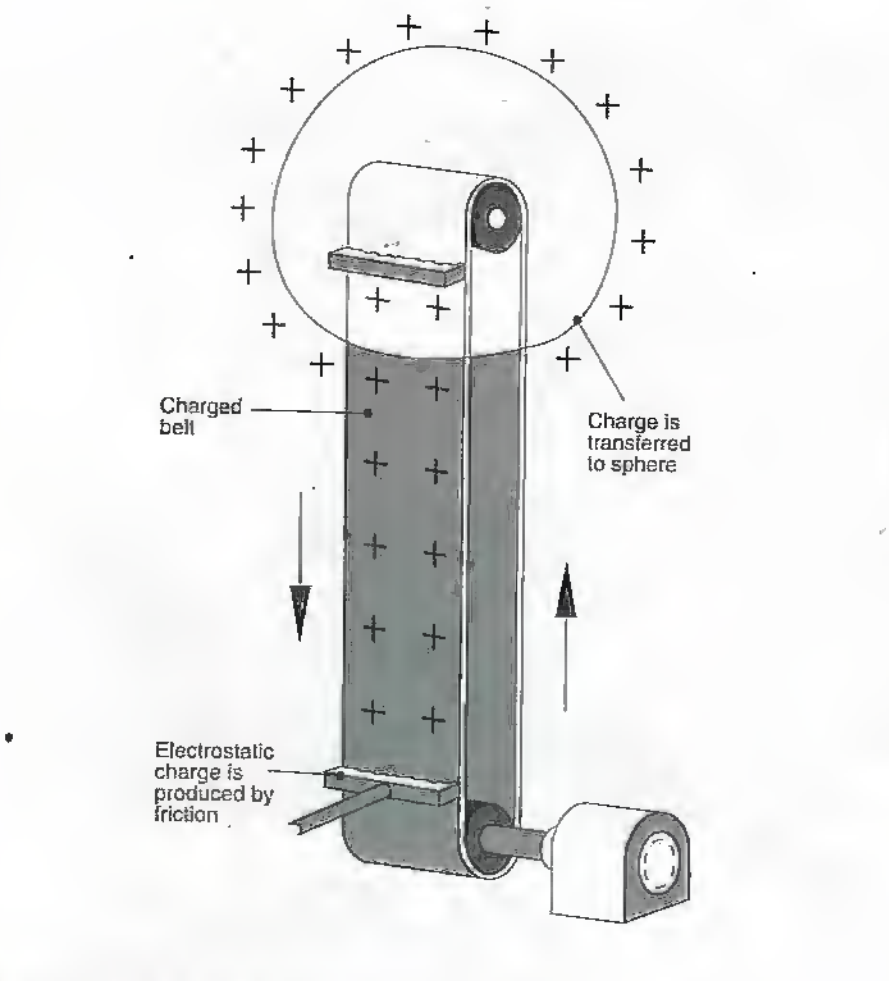
Charged belt
Charge is transferred to sphere
Electrostatic charge is produced by friction

Figure 1. The van de Graaf Generator of 1929.

James Wimshurst was a Londoner, the son of the constructor of the first two screw-propelled ships. After an apprenticeship at the Thames Ironworks and a post as a Surveyor of Lloyds, he became interested in what was then known as electrical influence machines. By 1880, he had built a number of the types then available, but was unhappy with their performance. He decided that he'd design and build his own model, which he termed a *Duplex Machine*, but which came to be known simply as the Wimshurst Machine a huge, two-plate example of which he presented to the Science Museum.

By 1896, he discovered that this massive machine was an excellent generator of X rays. It was also used in hospitals for producing powerful brush discharges, at that time thought to be a worthwhile method of treating cancers, among other things! Indeed, it would remain the only machine of its kind until well into the present century.

Cockcroft and Walton's Voltage Multiplier

The first true particle accelerator was built by the British physicist John Cockroft and his Irish colleague Ernest Walton, at Cambridge. They devised a voltage multiplier that built up a high electrical voltage, capable of accelerating protons such that they displayed very considerable energy, or speed. In this context, *speed* and *energy* mean one and the same thing.

The Cockcroft and Walton multiplier generated some 400,000V and, in 1932, the pair succeeded in boosting protons to an energy level such that they managed to break up the nuclei of lithium atoms. This was the experiment that really began the nuclear age, and in 1951 it won the pair the Nobel Prize in physics.

The van de Graaff Generator

In 1929, the American engineer Robert van de Graaf arrived at Oxford as a Rhodes Scholar, and took an immediate interest in the Wimshurst Machine. He realised that it could be considerably improved by storing the charge on a hollow metal sphere.

The sphere was placed on top of an insulating column, the charge being built-up on a high speed belt. This belt, made of insulating material, separated electrons from protons, depositing them at opposite ends of the machine. Van de Graaf's first machine - which he termed a generator - produced a potential of 8 Megavolts (Mv). Later, using chlorofluorocarbons - the now-infamous CFCs - or high pressure nitrogen, van de Graaf increased his generator's output to 14Mv.

There were, however, limitations to what such machines could achieve in particle physics research. Whilst their output was an improvement over Wimshurst's earlier models, far higher voltages were required to take particle physics further than they'd been taken by Cockcroft and Walton.

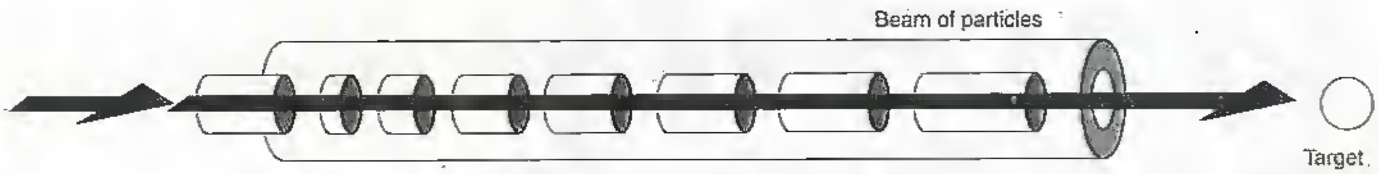

Figure 2. The Linear Accelerator, or Linac, of 1939.

Linear Acceleration

The Linear Accelerator was developed in 1939. Commonly known as the *Linac*, a rather obvious dual-element derivative, this machine - illustrated in Figure 2 - accelerated particles in stages. The particles passed through a series of metal tubes, to which accurately timed voltages were applied, boosting the particle beam to speeds closely approaching that of light.

There was, of course, an obvious snag with the Linac: its size. To achieve the bean energies required, such machines had to be several kilometres long. The American physicist Ernest Orlando Lawrence however proposed a solution to this problem: make the particle path circular.

The Cyclotron

In 1930, after some two years of development work, Lawrence built a 30.5 centimetre (cm) diameter *Magnetic Resonance Accelerator*, at the University of California at Berkeley. The principle is illustrated in Figure 3.

In this design, the particle path was bent into a spiral by two D-shaped magnets, to which an ac voltage had been applied, thus generating fields which alternately pushed and pulled. As the beam's energy increased, its path swung closer and closer to the instrument's rim until it shot through a slit to bombard its target.

Although his original model was small, Lawrence achieved energies greater than a million electron volts, or 1MeV, with it. However, he disliked the name *Cyclotron* - derived from the fact that the particles travelled in what was, in effect, a circular *Linac* - regarding it as a piece of laboratory slang. Hence his rather grand alternative.

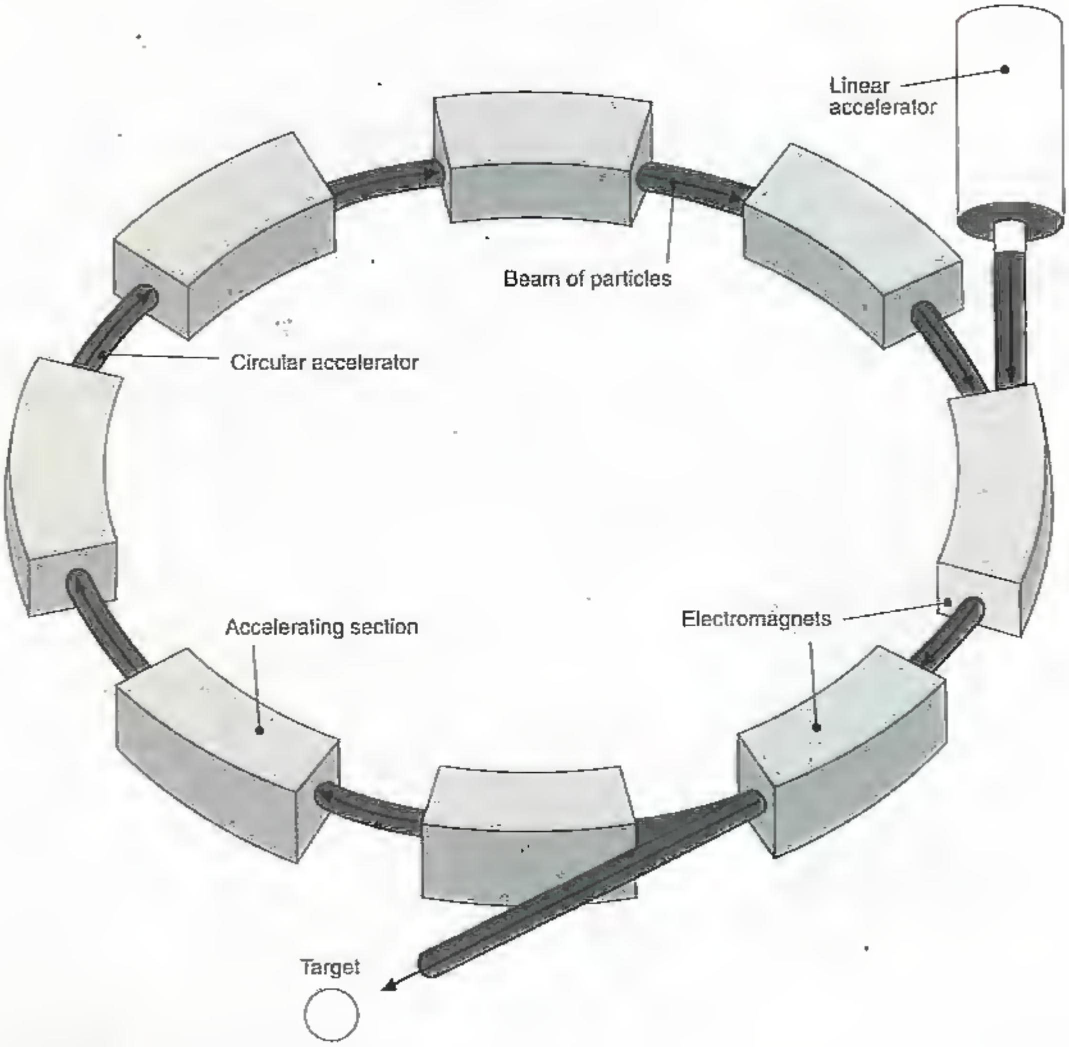

Figure 3. The principle of the Cyclotron, of 1930.

Nine years later, Lawrence built a 1.5m diameter version of his original machine, which produced energies of the order of 20MeV. This, in turn, brought its own problems. The particles, as a result of their speed - which was some 90% of the speed of light - greatly increased in mass, resulting in their lagging behind and falling out of synchronisation with the alternating field.

This problem was overcome by a further development of Lawrence's original machine, which was termed the Synchrocyclotron. As its name implied, this machine synchronised the supply frequency of the field with the mass increase of the particles.

The Betatron

Accelerating protons was one thing: doing the same to electrons quite another, for they're far smaller particles than protons. In 1940 however, a machine for doing exactly this was developed at the University of Illinois, under the direction of the physicist Donald W. Kerst.

At the beginning of the century, electrons had been known as *beta* particles, from the second letter of the Greek alphabet. Consequently Kerst termed his machine a *Betatron* another, fairly obvious, dual-element derivative.

Structurally, the betatron was an evacuated tube formed into a circular loop, which was embedded in an electromagnet whose windings were parallel to the loop. AC current in the windings produced a varying magnetic field which periodically reversed direction.

Large betatrons have produced electron beams with energies in excess of 340MeV. There is, however, one problem with these machines - their weight. The 340MeV device for example weighs a considerable 330 tons, almost a ton for every 1MeV!

Mega Monsters

Big as such machine are, they've been dwarfed by the giant particle colliders now either up and running, or about to be, in both Europe and America.

As noted earlier, the problem with particle accelerators was relativity, which applied a natural law of diminishing returns in that the closer such techniques approached the speed of light, the greater the difficulties caused by increasing particle mass. Science however saw a way forward in the Particle Collider, in which particles are accelerated in one direction, and antiparticles in the opposite direction, and then brought into collision.

One such machine is the *Tevatron*, built at the Fermi National Accelerator laboratory in Illinois in 1983. Its circumference is some 6.3 kilometres (km) and it uses superconducting magnets, cooled by liquid helium, to produce a field sufficient to accelerate protons in one direction and antiprotons in the other. This machine's collision detector is a massive 5,000 tons and it achieves energies of 1.8tera - or million-million - eV!

In 1989, the Conseil Européen pour la Recherche Nucleaire (CERN) finally completed its *Large Electron-Positron Collider*, or *LEP*.

This huge machine is 26.7 km in circumference and has no less than four gigantic collision detectors called *Aleph*, *Delphi*, L3 and *Opal*. The events they observe are collisions of the order of 100 billion eV!

Presently however, big scientific machines appear to be going out of fashion, certainly with the people who control national wallets. In 1989 for example, the Americans began work on the most ambitious particle investigation machine yet devised, the Superconducting Super Collider, or SSC. This massive piece of equipment was going to occupy an oval tunnel no less than 85km long!

The budget had been estimated at a staggering 11 billion dollars. After some 2 billion of this sum had bought a mere 16km of tunnel, the United States Congress called a halt. It concluded there were far more worthwhile - not to say readily understandable - projects at which this kind of money could be thrown.

In Europe, CERN had considered building an investigative piece of equipment every bit as massive as the SSC, the *Large Hadron Collider*, or *LHC*. This, it was intended, would use an existing tunnel under the Jura Mountains near Geneva. Thus far however, this seems unlikely. Economic relativity, it would appear, is every bit as limiting as its scientific cousin!

Next month, in the final piece in the series, we'll look at how an alphabet - or the lack of one - could have influenced the history of technology over the last two millennium.

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MAPLIN ELECTRONICS

THE WORLD OF 3D

PART 2

In part two, Mike Bedford looks at holography and stereoscopic CRT screens.

Last month we introduced the subject of the third dimension and saw how ordinary cameras, computer monitors, TVs and cinema screens are able - at least in part - to fool us into perceiving depth, even though we're looking at something which is perfectly flat. This is achieved by reproducing various so-called visual depth cues such as perspective, shading, shadowing and the like. But, of course, this isn't what most people mean when they talk about 3D. So the main part of the article looked at the various ways in which another important depth cue, binocular disparity, is recorded photographically or generated by computer and how the resultant stereograms can be displayed. We saw that, to reproduce binocular disparity, it's necessary to generate two images, one for the left eye and one for the right. We also saw that some viewing method then has to be devised such that each eye only sees the image created for that eye. We saw various method by which this could be achieved but all can be summed up by the word stereoscopy. Exactly why stereoscopy makes us perceive depth in such a spectacular way is hard to say – I guess it's all tied up with the way our brains process visual information – but most people find the results pretty spectacular.

But impressive as the various types of stereogram might be, the technique only adds binocular disparity to the depth cues already present in conventional photography or computer graphics. You will have discovered if you read last month's article, that there are a further two visual depth cues which stereoscopy doesn't give us. The first of these is ocular accommodation which is the ability to selectively focus our eyes on objects at different distances, and the second is motion parallax. Here, as we move our head from side to side, the view changes with object moving in front of more distant objects which happen to be in a direct line with our eyes. Our first topic this month is holography, a special type of photography which is able to reproduce every single visual depth cue. This month we'll be concerned purely with conventional holography but this will lay the foundations necessary to understand the research into computer-generated holographic hardcopy and electronic holographic displays which we'll investigate next month. Our second main topic in this month's article is the various ways in which stereoscopy can be brought to electronic displays. Unlike the quest for electronic holography, this is technology which is widely available today.

Holography

Despite the fact that the hologram is a relatively recent introduction, the word is now in everyday use. Perhaps this is due to the proliferation of so-called holographic projections in Star Wars and the like although these are most definitely in the realm of science fiction rather than science fact. More likely, it has something to do with the tiny holographic stickers which now adorn credit cards and the boxes in which Microsoft Windows is distributed. However, the impact of these mass produced holograms falls far short of that of true silver halide holograms and it's probably true to say that most people have never seen these fully featured holograms.

When an ordinary photograph is taken using a conventional camera, a lens focuses light onto the film such that each point on the film receives light reflected off a particular point in the scene being captured. The properties of the film then allow the reflected light intensity from each of these points to be recorded. This gives a two dimensional representation but – with the exception of the implied information in depth cues such as perspective and shading – no information regarding depth is recorded. At this point, let me remind you that light is a waveform. Let me also remind you that laser light is referred to as being coherent. This means that it is monochromatic and that all the waves are in phase. If, however, a laser beam is reflected of some object, the waves in the reflected beam will differ in phase, the phase difference being a function of the relative distance each wave had travelled. So, if some method could be devised such that the phase of light, and not just its intensity, could be recorded then we would have enough information to reconstruct a proper three dimensional image. This is the principle behind holography – let's see how it works in a more detail.

Simply taking a photograph in the normal way but using a laser instead of a more conventional light source does not produce a hologram since the phase information won't be recorded. Instead, some sort of reference is required against which the phase of the waves in the beam reflected off the subject can be compared. This is achieved by splitting the laser beam using a semi-silvered mirror as shown in the illustration. If the reference beam can be made to coincide with the beam reflected off the subject, an interference pattern of light and dark fringes is created. The interference pattern contains information about the phase difference between the reference and the object beam and, if the

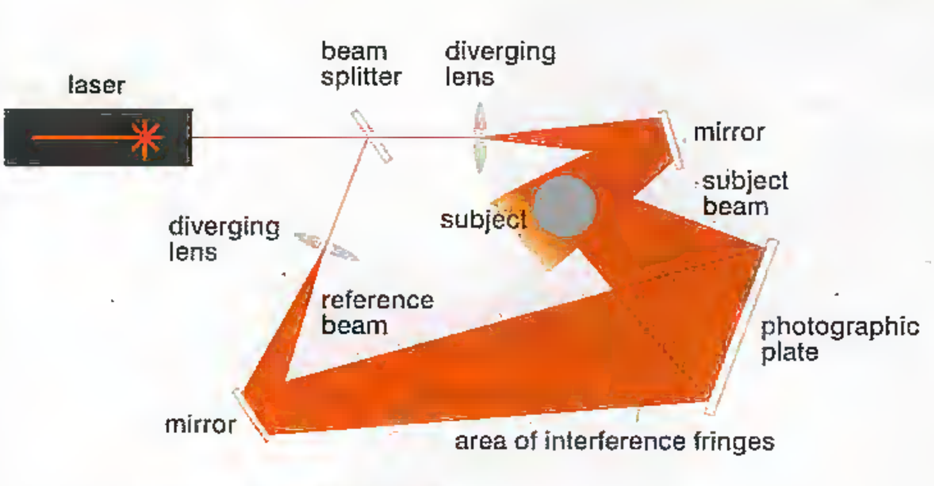


Figure 1. Photographic recording of a hologram.

two beams are made to coincide on a very high resolution film, this pattern can be recorded photographically. See Figure 1.

It's important to note, however, that a hologram is not an image in the same way that a photograph is an image. In other words, one point on the hologram does not correspond to a particular point in the recorded scene. Since a lens hasn't been used to focus the light onto the plane, each point in the scene ends up illuminating many parts of the hologram. All of this gives rise to a number of intriguing properties of a hologram. First of all, since the hologram contains light which was reflected off the object in many different directions, it contains information which should allow images from multiple viewpoints to be recorded. However, and here we come to our second point, when you look at a hologram (or more specifically a transmission hologram) in white light you don't see the object which is recorded in it. It's appropriate to investigate, therefore, just how we do view a hologram. As you'll be aware, one way to bend light is to use a lens. Another way is to use the fine interference patterns of a hologram which can be thought of as a very complicated lens. So, if you shine a beam of laser light at the hologram from the same direction that the reference beam was shone to generate it, the interference patterns in the hologram bends the light into various directions equivalent to the directions at which light hit the hologram during its creation. So as you look through the hologram you see the object in full 3D at the other side of the hologram as if it were a window into the original scene. And that scene really is in full 3D. Not only do you get binocular disparity since each eye will see a slightly different image, but as you move your head from side to side or up and down then the scene will change. You'll see the scene from different angles and objects will move in front of other objects. I've even seen a hologram which included a magnifying glass. If you moved your head so that you were 'looking through' the magnifying glass then the objects behind it were indeed magnified. Now that's what I call real 3D!

Interestingly, to view a hologram you don't have to use a laser beam of the same wavelength as that used to create it.

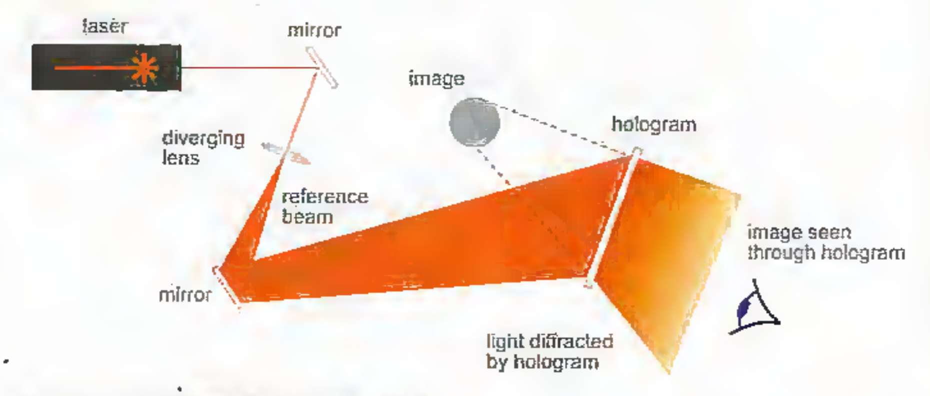


Figure 1. How a hologram is reproduced.

However, the apparent size of the object and it's distance behind the hologram will vary if you use a different wavelength. For example, if you create a hologram using a red laser and view it using a blue laser, the object will appear smaller than it actually was. This also illustrates why it isn't possible to view a conventional hologram using an ordinary white light source. Since the hologram will defract all colours of light – not just the colour used to create it – you'll end up seeing multiple images or different sizes each in a different colour. It might vaguely resemble the original scene but that's about all. However, some types of holograms, and specifically reflection holograms – as opposed to the transmission holograms we've already seen –can be viewed in white light so long as it comes from a point source. A reflection hologram is created by shining the reference beam onto the opposite side of the photographic film from the object beam. And now, of course, since the illumination of a hologram has to be from the same direction as the reference beam during its creation, it is illuminated from the same side as the viewer. In other words, viewing a reflection hologram is like viewing an ordinary photograph. However, the properties of a reflection hologram causes all but a single wavelength of the light used to illuminate it to be absorbed by the film. Only a single wavelength is reflected, therefore, and the viewer sees just a single image in a single colour. Many of the mass produced holograms are of the reflection type but are specifically embossed as opposed to being created on photographic film. This gives rise to the well know rainbow effect – as you move your head, though, the specific colour of reflected light will change and the image can be viewed in a whole range of colours. See Figure 2.

All that we've seen in this series so far concerns conventional techniques for creating and viewing three dimensional images – either stereograms or holograms. Admittedly we looked last month at how computers ease the production and display of left-right stereo pairs, of anaglyphs of various types and of single image random dot stereograms and Magic Eye images. Nevertheless, many of the techniques would have been familiar to Victorian stereoscopists. Although this month's coverage of holography is much more up to date, with the exception of the laser which is used to create and view a hologram, this doesn't have much to do with electronics. However, all we've covered so far is essential background material to our next topic, 3D viewing methods designed specifically for the computer display and for television.

Stereoscopic CRT Screens

Having just looked at the magical world of holography, you might feel that a return to stereoscopy is a retrograde step, and in a way it is although most people do, nevertheless, find stereoscopic images pretty impressive. However, since techniques for computer generated holograms, holographic TV and video are still very much at the pioneering stage it

Anaglyph of Martian landscape.

Anaglyph of Pathfinder on Mars.

seems appropriate to start off our investigations with technology which is available today. Actually, we've already seen two possible ways in which stereoscopic images could be displayed on a computer or TV screen. The first method is to display a left-right stereo pair on the screen and the second is to use anaglyphs, but neither is ideal. Stereo pairs place constraints on the size and/or viewing distance and angle whereas anaglyphs can compromise colour rendition. Nevertheless, anaglyphs can be found on the Web for on-line viewing as the two images of the Martian surface photographed by the recent NASA mission to the Red Planet and displayed on their Web site shows. One is a Martian scene containing the 'twin peaks' taken from the Pathfinder lander whereas the other is a shot of the Pathfinder and its airbags taken from the Sojourner rover. Clearly analgyphs can have a more up to date image than 50s horror movies. If you didn't obtain a pair of red-blue glasses to view the anaglyphs in last month's article but want to see these images in 3D, see the end of this article for details of where to get a pair.

The next method of stereoscopic display on a CRT which we're about to look at has none of the drawbacks of conventional stereoscopy. First of all, a stereoscopic pair of images is generated and each is placed in its own video buffer on a specially adapted graphics card. Now, the two images are displayed alternately on the CRT at a high frequency. Normally, this is done at double the intended refresh rate. For example, if you require a 70Hz refresh rate, the two images would have to be switched at a frequency of 140Hz and this clearly places stringent constraints on the monitor. If you were to look at the CRT in the normal way you'd get a result which is not dissimilar to that you get if you look at an anaglyph without wearing red-blue funny glasses. The picture would be recognisable but it would be blurred since you'd actually be seeing two slightly different photographs at the same time. To avoid this and, in so doing, see the image with full binocular disparity, you have to wear a special pair or glasses. Each lens is an LCD shutter, that is a liquid crystal filter which can be made transparent or opaque depending on whether or not an electrical potential is applied. The glasses connect to the display hardware and this drives the lenses in a way which is synchronised to the switching of the images on the screen. So, when the left eye's image is displayed on the screen the left lens is made transparent and the right lens opaque. And when the right eye's image is displayed on the screen the right lens is made transparent and the left lens opaque. Clearly, as with all the other methods of stereoscopic reproduction we saw last month, each eye sees only the image generated for that eye and the result is three dimensional. See Figure 3.

But, of course, there's a snag with this method of stereoscopy. Most people don't like to have to wear the cardboard glasses which are used for viewing anaglyphic photographs or movies but the LCD shutter glasses are even less user friendly. For a start the user ends up tethered to the display hardware via a cable and secondly, the glasses are heavy. Furthermore, the solution becomes even more unwieldy with multiple viewers – it certainly wouldn't lend itself to video projection. OK, a few companies have produced wireless LCD shutter glasses which communicate with the display equipment via an infra red link but this doesn't solve the weight problem, in fact we might reasonably expect that these glasses will be even heavier. An alternative technology, therefore, uses passive glasses. Still not everyone's cup of tea, admittedly, but it's a major improvement on the active system. Here, rather than put active LCD shutters immediately in front of the viewers eyes, an active screen is placed directly in front of the monitor or video projector. This screen can be made to polarise the light in different directions depending on the applied electrical potential. Once again, this screen is synchronised to the swapping of

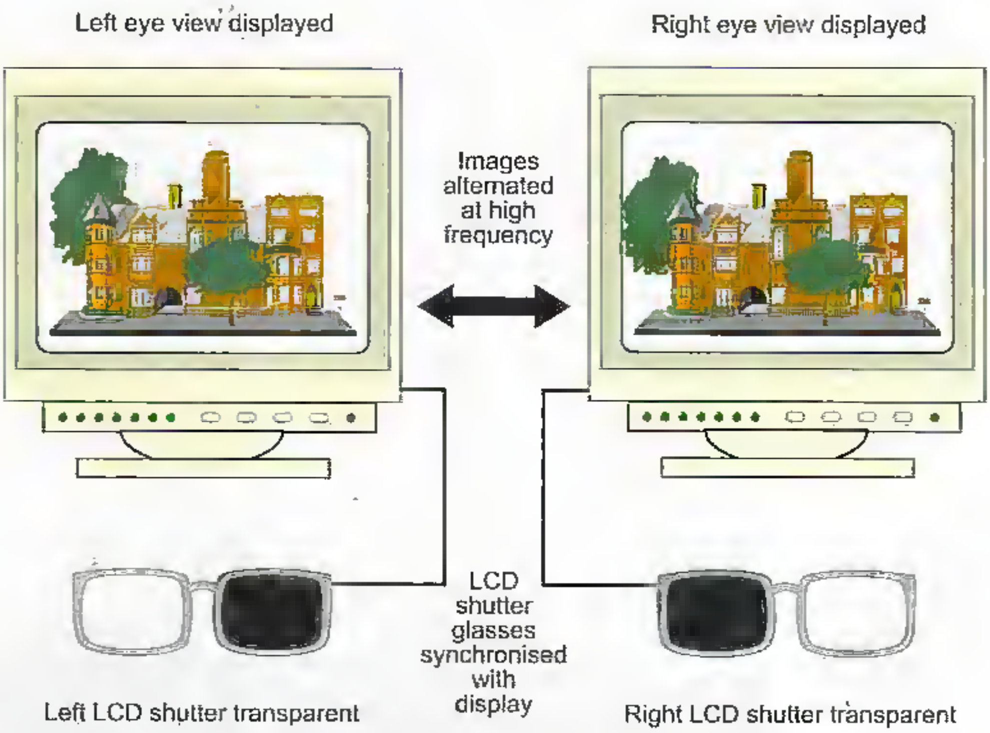

Left eye view displayed
Right eye view displayed
Images alternated at high frequency
LCD shutter glasses synchronised with display
Left LCD shutter transparent
Right LCD shutter transparent

Figure 3. Stereoscopic display on a CRT, but this requires very elaborate glasses.

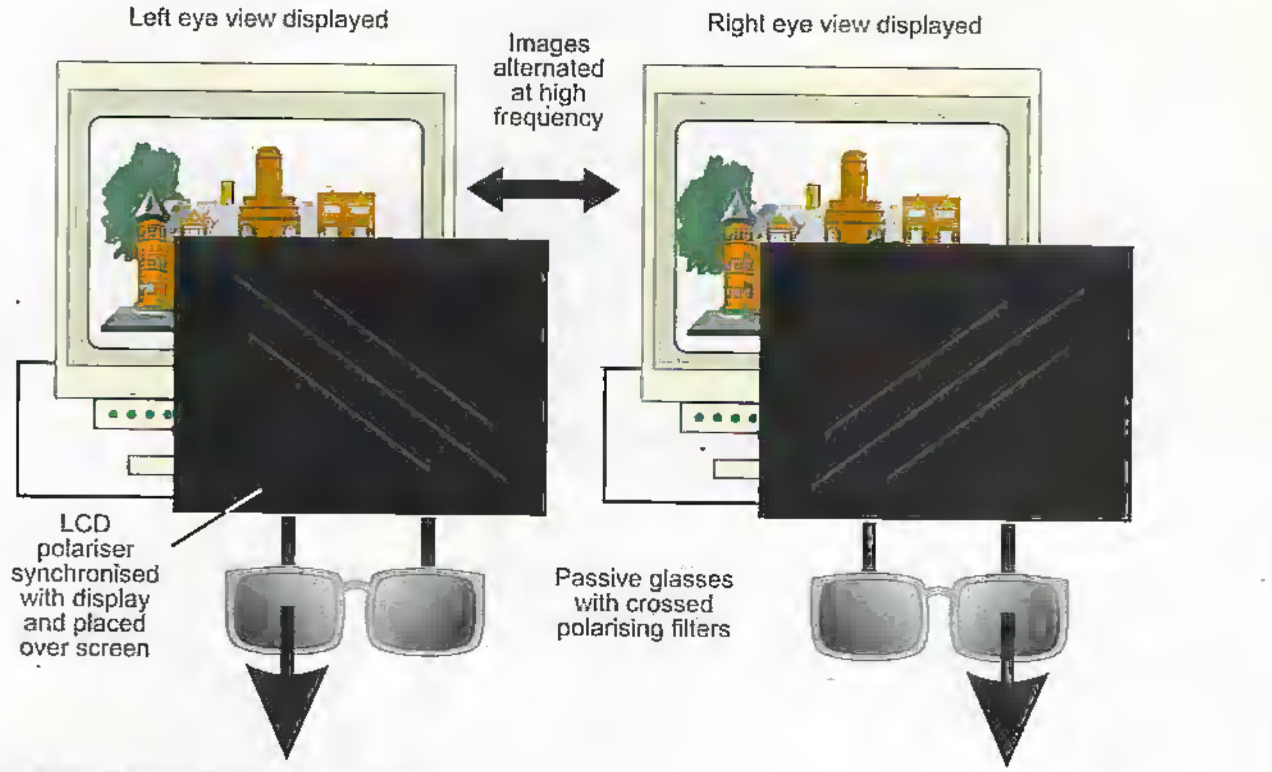

Left eye view displayed
Images alternated at high frequency
Right eye view displayed
LCD polariser synchronised with display and placed over screen
Passive glasses with crossed polarising filters

Figure 4. Stereoscopic display using passive glasses.

the on-screen images such that the left eye's image is polarised differently from the right eye's image. Now all that is needed is a pair of passive glasses with crossed polarising filters such as those which are used for conventional projection of photographic stereo pairs. See Figure 4.

Head-mounted Displays

Perhaps the most obvious and easy method of viewing a stereo pair is the method employed all those years ago by the Victorian photographers who popularised 3D. It is also the method used in the Viewmaster 3D viewer. Simply put two small images side by side and use some simple optics to ensure that each is seen by one eye and one eye only. And unlike free viewing of left-right stereograms this method doesn't require you to learn some rather unnatural viewing method. The next method of displaying a stereo pair of electronic images is basically this method brought up to date. As we'll see, though, when this technique is used in conjunction with a real time image generation system, exciting new possibilities present themselves.

The system I'm talking about is the head-mounted display which generally tends to be associated with virtual reality. What makes this so appropriate for virtual reality applications is that it provides a so-called immersive environment. If you sit in front of a TV screen or computer monitor the image on the screen doesn't fill your entire field of view. So however compelling the story line of the film your watching or however gripping the action in the latest version of Tomb Raider, you're not going to loose sight of the fact that you're actually sitting in your lounge or study. The aim of virtual reality, however, is to make you loose sight of where you actually are and start to think that you're in the world displayed on the screen. And to do this the image needs to wrap around you completely. This is achieved by displaying the image on a tiny LCD screen very close to your eyes and using optics to allow you to focus on the image and make it fill your field of view. However, if, instead of one, you have two LCD screens, one in front of each eye and each with its own optics, stereoscopy becomes possible. And now you don't just have an immersive environment but you also have one which is in 3D. Well almost, certainly binocular disparity is added and, as we know, this can be one of the most effective visual depth cues.

But as we also know, it's not the only depth cue which is missing from a conventional photograph or electronic display. The remaining two are ocular accommodation and motion parallax and, so far, we've only seen holography which can reproduce them. With pre-recorded video footage the head-mounted display is only ever going to give us binocular disparity. However, if we're concerned with real time computer generated images then motion parallax also becomes possible, so long as we fit a motion sensor to the head-mounted display that is. Now, as the user's head moves from side to side or up and down, the computer can determine the direction of view and re-calculate and display the image accordingly. Clearly this can provide motion parallax but the technique goes beyond this. As an alternative to moving to the left and right or up and down, the user might choose to turn round. And now, of course, it isn't just a matter of seeing the same scene from a slightly different viewpoint but of seeing a totally different scene. Once again, this isn't a problem if the graphics is being generated in real time. Strictly speaking this is more to do with maintaining the immersive environment than providing another visual depth cue but it is, nevertheless, another way in which the electronic image can become more convincing.

Volumetric Displays

Next month, to complete our series, we'll look at various three dimensional display technologies which are still at the forefront of technology. And this is also where we'll complete this particular instalment. Specifically we'll look at a possible technology which seems so obvious but is still very much experimental. As we'll see, however, despite the fact that research into this form of display continues, it does rather appear that the technology is something of a blind alley.

I know that it's very difficult to try to un-learn something but, for the moment, try to forget all we've covered in the series so far. In other words, forget about stereoscopy and forget about holography. After all, in some ways these are not exactly intuitive approaches. They are, despite appearances to the contrary, both ways of recording depth information in something which is actually two dimensional. How might you design a 3D display if you were starting from scratch with no pre-perceived notions? Might you take the approach of designing a display which is actually three dimensional rather than flat? Certainly it seems rather strange in the light of the other approaches we've learned about but in many ways it's surely the obvious solution. Such a device is called a volumetric display and is the three dimensional equivalent of an LCD or CRT screen. Instead of a flat surface in which any pixel on that surface can be illuminated in any colour, a volumetric display is a cube in which any three-dimensional pixel or 'voxel' anywhere inside that cube can be illuminated. One way of constructing a volumetric display would be to assemble a three dimensional array of LEDs. The image is then written to the display in much the same way as an image is written to a two dimensional display. Simply light up the appropriate LEDs to create an image of the three dimensional object.Since the object truly would be three dimensional then the various depth cues which we've seen will all be there. Of course, the image would only be small, nothing would be more than a metre or so away so many of the visual depth cues such as colour gradient which are only appreciable at distant wouldn't be seen. Ironically, though, some of the trickier ones to reproduce on a flat surface – binocular disparity, ocular accommodation and motion parallax – would all be present.

This method of constructing a volumetric display is by no means a practical proposition of course – it was provided purely as an easy to understand illustration. The difficulties which come to mind are how to support the LEDs and how to wire them up such that the supports and wiring aren't visible and don't obscure other LEDs. Most serious work on volumetric displays has involved filing the cube with some fluorescent material and causing a particular voxel to illuminate by exciting it with laser beams. The usual approach is to address a voxel using a pair of laser beams. By picking an appropriate fluorescent material and appropriate lasers it's possible to arrange that fluorescence will only take place at a voxel where the two beams intersect. Now, of course, we have a means of addressing voxels in three dimensions.

All of this sounds very convincing at first sight but there is a snag. Voxels could be illuminated, certainly; depending on the technology it might be possible to illuminate them in any colour; and voxels could be turned off. What it wouldn't be possible to do, however, is to make them opaque. So motion parallax of a sort would be possible – objects would appear to move relative to closer or more distant objects as you move your head but it wouldn't be possible for one object to obscure a more distant object. In other words, objects will all be transparent or translucent so a volumetric display would produce the three dimensional equivalent of a wire frame model. This would be useful for some tasks such as engineering design, admittedly, but it doesn't seem that it would lend itself to general 3D imaging where photo-reality is a requirement.

Auto-stereoscopic Systems

In many respects the volumetric display is far from ideal but it does have one important property which, so far, we haven't seen in an electronic display – it is auto-stereoscopic. In other words the viewer doesn't have to wear glasses or make use of any other viewing aid. This is the usual definition of auto-stereoscopic but I'd like to add one additional constraint, namely that the viewer doesn't have to engage in the sort of visual gymnastics which are required to free view left-right stereo pairs or Magic Eye images. A stereoscopic display or hardcopy, therefore is one in which the scene appears three dimensional just by looking at it in the normal way. In this series we've only seen one practical method of three dimensional imaging which has this property and this isn't an electronic display. That one autostereoscopic imaging technique is holography. Most of today's research into electronic 3D imaging and computer 3D hardcopy is concerned with auto-stereoscopy and as we conclude our look at the third dimension in next month's article we'll see a number of systems which are currently being put through their paces in the development laboratories.

Sources

Remember that if you need a pair or red-blue glasses to view the various anaglyphs in last month's article or the one of the Martian surface in this article, these are freely available. 3D Images Ltd. will supply two free pairs of glasses (red-green, red-blue or one of each). To take advantage of this offer, send a stamped self-addressed envelope to 3D Images Ltd. at 31 The Chine, Grange Park, London, N21 2EA.

A wide range of 3D products and services are available from 3D Images Ltd at 0181 364 0022 or `http://www.stereoscopy.com/3d-images`. The company specialises in most 3D technologies including anaglyphs, lenticular stereograms, side-by-side stereo pairs, Magic Eye type stereograms and holograms. They can also provide stereo cameras (including digital), stereo projection systems and LCD shutter displays.

Spatial Imaging Ltd. is a supplier of commercial holographic services and equipment, mainly for security and display purposes. The company can be contacted on 0181 332 1948 or you may like to take a look at their Web site at `http://www.holograms.co.uk` where there is a wealth of information on 3D imaging.

If, on the other hand, you have no commercial use for holography but find this a fascinating area, you might be interested in Laza Holograms who sell from stock silver halide reflection holograms in 1-off quantities. Contact 01276 683000 for a catalogue.

Canon BJC-7100 Colour Printer
Canon BJC-6000 Colour Printer
Canon BJC-4300 Colour Printer
Canon BJC-2000 Colour Printer

Canon BUBBLE JET PRINTERS

John Mosely tries out the very latest colour printers from Canon.

Canon has introduced four new colour bubble jet printers to there range - from the budget BJC-2000 to the fast, high performance BJC-7100. Each one offers a range of features suited to your needs for use in the home to cost effective business and professional printing requirements.

Canon's patented Drop Modulation Technology is used to produce quality colour printouts by varying the size of the ink drops. Images are created by using dots of different sizes and colour - small dots for areas of low colour saturation and fine detail, and large dots for saturated areas and solid blocks. Canon claim this results in images that have greater depth of colour and subtlety of shading.

All the printers can cope with a wide range of print media, and feature automatic sheet feed. At the front of each printer is a pull-out tray to hold the printed page.

BJC-2000

The BJC-2000 is 30% smaller than the current BJC-4300, and is claimed to be one of the smallest desktop printers available. But it is designed to meet the needs of mono, colour and photo quality printed output, and so is ideally suited for the home user who requires quality at a realistic price.

This printer is very easy to install and set-up. The front cover is pulled down and the ink cartridge carrier automatically centres itself, the cartridges are then literally dropped into the carrier. Driver installation software is supplied on CD-ROM and installed in minutes.

In use the printer is reasonably quiet and simple text documents were printed quickly. Results were more than adequate for normal home and small business use. Colour printing was much slower, especially when the photo cartridge was used, but when using glossy photo quality paper, the printed results were extremely good. Obviously, print

Canon COLOR BUBBLE JET PRINTER BJC-2000
Hair & Make-up
For a touch of celebrity treatment
Stardust Salon

speed is dependent on size of image, and amount of text. Canon claim anything up to 4.5ppm for mono printing, and up to 2ppm for colour using the BC-21e colour cartridge.

One other feature that makes the BJC-2000 very versatile is the ability to convert to a colour image scanner. The optional scanner cartridge replaces the ink cartridge and allows the user to scan photos, images and documents straight onto your PC.

The printer can accept a wide range of paper types and sizes - A4, B5, A5 legal, envelopes - plus it will also print on to fabric sheet and T-shirt transfers in addition to transparency and black print film.

If I have one minor gripe, then it has to be the lack of any visual indication that the printer is on.

Features

- Compact size
- 4.5ppm mono printing, 2ppm colour graphics
- 720 x 360dpi resolution with drop modulation technology
- Fast drop-in cartridge change
- Optional IS-22 scanner cartridge
- Excellent value for money

Canon BJC-2000

Print Quality ★★★½☆
Speed ★★★☆☆
Overall value ★★★★★

Item	Order code	Price inc. VAT
BJC-2000	PZ35Q	£119.99
BC20 mono cart	KX55K	£29.99
BC21 colour cart	KX56L	£45.99
BC22 photo cart	KX60R	£30.99
BC29 fluorescent cart	KX62S	£34.99
IS-22 scanner head	LY28F	£79.99

BJC-4400Photo

This model is primarily aimed at users who are particularly interested in photo quality printing at an affordable price - whether in the home or office environment. Compared to the BJC-4300 mono printing speed has increased by 30% - up to 6.5ppm. Colour printing using the BC-21e colour graphics cartridge is up to 2.3ppm. Specially developed inks used in the BC22e cartridge (included with the printer) give excellent true-to-life results, plus the printer driver includes 'image optimiser' which is intended to increase the quality of low resolution images. Using the standard BC21e colour cartridge 720 x 360 dpi resolution is achieved, which is also achievable with the mono cartridge with smoothing.

The sheet feeder has a capacity of up to 100 and will accept 64 to 105gsm paper, which is similar to the BJC-2000. Again, using the IS-22 optional scanner cartridge turns the printer into a 360 x 360dpi, 24-bit scanner.

Bundled with the printer, along with the BC22e cartridge, is a pack of glossy photo paper, plus a full version of the best selling MGI PhotoSuite II image manipulation software which carries a retail price of £49.99.

Again, installing and setting up the printer could not be easier, with software supplied on CD-ROM. The results were again very good. It has to be said that if you use the photo paper and the photo cartridge, then the results are astonishing. We used images from a Kodak Photo CD, and used PhotoSuite II to output the images to all the printers reviewed here.

Canon
Canon
Canon COLOR BUBBLE JET PRINTER
Hair & Make-up
For a touch of celebrity treatment
Stardust Salon

Features

- 6.5ppm mono printing, 2.3ppm colour
- High quality general colour printing 720 x 360dpi with drop modulation technology
- Photo cartridge and paper samples
- Optional IS-22 scanner cartridge
- MGI Photosuite II imaging software

BUBBLE JET PRINTER BJC-6000
1 Color and BC-32 Photo cartridge

Canon BJC-4400

Print Quality	★★★★☆
Speed	★★★☆☆
Overall value	★★★★☆

Item	Order code	Price inc. VAT
BJC-4400	PZ36P	£149.99
BC20 mono cart	KX35Q	£29.99
BC21 colour cart	KX56L	£45.99
BC22 photo cart	KX60R	£30.99
BC29 fluorescent cart	KX62S	£34.99
IS-22 scanner head	LY28F	£79.99

BJC-6000

Print Quality	★★★★☆
Speed	★★★★☆
Overall value	★★★★★

Item	Order code	Price inc. VAT
BJC6000	PZ37S	£219.99
BC30 black cart	PZ55K	£33.99
BC31 colour cart	PZ57M	£37.49
BC32 photo cart	PZ61R	£37.49

BJC-6000

The BJC-6000 is intended to be a cost-effective business printer, primarily aimed at professional printing. The printer is based on a new four-colour print engine that features separate ink tanks, which can be configured as either mono/colour or colour/photo. All three print cartridges have separate replaceable ink tanks, which helps to reduce running costs, as only the ink tanks that are empty needed to be replaced.

The first immediate difference is that this printer is a lot bigger than the other two, and the ink tanks are correspondingly larger, so should have a lot longer life. This printer has been optimised for high speed printing - up to 8ppm in mono - and is possible due to bi-directional printing and multi-nozzle print heads. In colour this drops to a still impressive 5ppm, with a possible resolution of 1440 x 720dpi.

When it comes to handling different print media, then this printer is very versatile. It can cope with media up to 550gsm i.e. card, and size up to A4+ , that is full bleed.

Optical sensors monitor the individual cartridges for low ink levels and no ink, so that the user is prompted, when ink level is low and when the cartridge is empty. When this stage has been reached the printer will automatically stop printing.

Again installation and set up is very straight forward, all software being supplied on CD-ROM. However, the print heads do need to be aligned, and this is performed from within the printer maintenance window, after the software has been installed - a relatively easy task that takes a few minutes. In all cases, installation instructions are excellent, being provided on an A3 size sheet in an easy-to-follow diagrammatic layout.

This machine is much faster in mono and colour, results again were excellent. In draft mode, text printout was very fast, and results were very good. It is important to remember to select the print mode i.e. draft, text, graphic/text, photo etc., and the paper being used. The print mode has to match the cartridges installed, and if they don't you are politely reminded to change the relevant cartridge. The colour/photo cartridge combination certainly produced excellent photo reproduction.

Features

- 8ppm mono printing, 5ppm colour
- High quality output with pigmented black ink for laser-like text - 1440 x 720dpi drop modulation technology - 6-colour photo quality printing
- Twin-cartridge system
- 4-separate ink tanks for low-cost, low-waste efficiency
- New printer engine
- Flexible print media - to 550gsm, A4+ full bleed, banner

Typical printed image on photo paper - photo courtesy Eastman Kodak Company.

BJC-7100

This is one of Canon's top-end bubble jet printers, and is intended for office and professional use. In addition to the printing features already mentioned on the other models, the BJC-7100 includes the patented P-POP - plain paper optimised printing. P-POP technology coats plain paper just before the inks are applied, the inks then bond with the paper to produce water-fast results which Canon claim are of high optical density and exceptional clarity.

This printer employs a 7-colour photo cartridge system for improved photographic quality, with up to 25 levels of colour gradation. There is an image optimiser setting for low resolution input and a digital camera preset option for digital still images.

The results on plain paper are certainly very acceptable, and print speed was reasonable fast. Again, it's a case of ensuring you have the correct print set-up, if you want the best the printer can offer for a given print media. Text documents were printed out very fast especially in draft format - much quicker than our normally used H.P IIIP laser. In normal text mode quality was not quiet the same as the laser jet but still excellent. The ink tanks are much bigger than the two lower priced printers, so they should last for some time - depending on print content, off course. The question of how long the cartridges will last is a difficult one, for if you print lots of full-page A4 colour images, then cartridge life will obviously be shortened. If you can't stretch to a laser printer, then this printer is certainly a very good alternative.

Features

- ◆ P-POP technology for high clarity, water-fast results
- ◆ 1200 x 600dpi resolution across all media types
- ◆ Up to 550gsm weight media
- ◆ High speed, high performance printing in mono (8ppm) and photo quality (5pmin)
- ◆ Photo cartridge as standard
- ◆ Low-maintenance cartridge tanks
- ◆ Optional network connectivity
- ◆ Plug-and-play installation including the full version of MGI PhotoSuite II imaging software

Conclusion

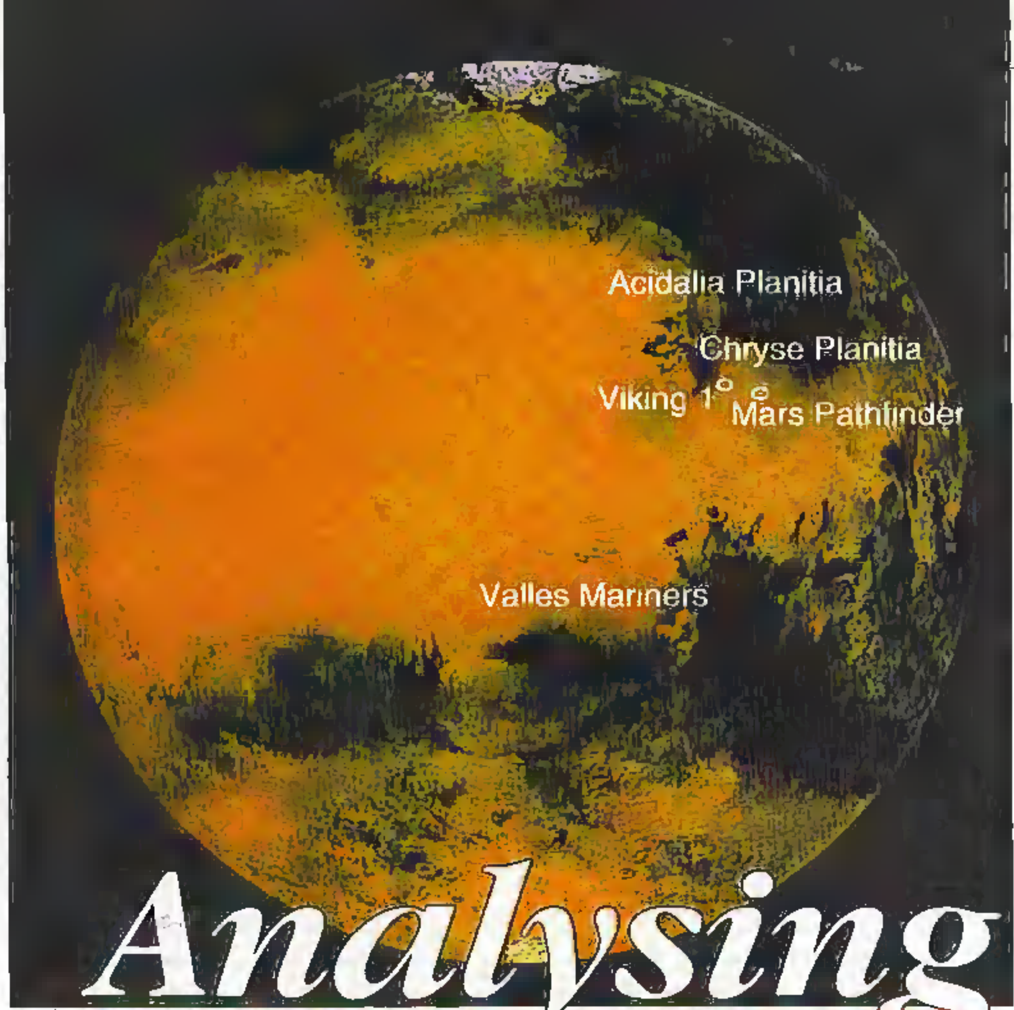
The price of printers has fallen over the years, yet the finished results and speed of printing have continued to improve. I use a two-year old Canon BJC-4200 at home, which has given me no problems, performs very well, but cost me about 25% more than the updated BJC-4400!

All the printers were easy to set up and install, and all worked first time. Set up documentation is excellent, with a manual included on the CD-ROM. They are all Windows 'plug-and-play' and suitable for Windows 3.1, 95 and 98. The one you select will obviously depend on the working environment and usage, but all should perform extremely well and give a long and trouble-free service. All the printers come with a one year on-site warranty.

Canon BJC-7100

Print Quality	★★★★½
Speed	★★★★
Overall value	★★★★★

Item	Order code	Price inc. VAT
BJC-7100	PZ38R	£269.99
BC60 mono cart	PZ77J	£32.99
BC61 colour cart	PZ78K	£33.99
BC62 photo cart	PZ80B	£49.99



Analysing MARS

In this article David Clark looks at some of the science behind one particular instrument used on the Pathfinder mission.

On the fourth of July 1997, after a seven month journey, a small craft successfully landed several scientific instruments on the surface of the red planet, Mars. The purpose of one of those instruments was the analysis of the composition of some of the material on that surface.

The mission (see Electronics and Beyond November 1998) returned some superb images and an enormous amount of data from the planet. One of the aspects of these explorations which captures the imagination of scientists, the media and general public alike is the search for indications of present or past life on the planets. But of at least equal value is the knowledge obtained about the composition of the surface, which provides clues about the formation of the planet and the solar system itself. Plans are underway for journeys in the near future which will explore below the surface of other planets and their moons, in particular possible oceans below an icy surface layer on Jupiter's moon Europa, which are thought to be perhaps the most likely site of some form of life. But how do these lifeless explorers analyse the material they come across on their out-of-this-world journeys? In this article I'll be looking at some of the science behind the main instrument which sampled the Martian soil, the science-fiction sounding Alpha-Proton X-ray Spectrometer.

What is a spectrometer?

Literally meaning 'measures the spectrum', the spectrometer is the device that obtains the 'raw' data making up the spectrum from which (hopefully!) meaningful information can be deduced. Spectroscopy is a general term for the analysis of these spectra which are a graphical representation of the ranges and intensities of the energy emitted or absorbed by matter as a consequence of the behaviour of its atoms, and of the particles which make up the atom, ie the protons, neutrons and electrons (see text at the end of the article). The term covers a broad range of techniques, but a simple example is visible light spectroscopy which enables information about a star to be found from analysing the different colours present in the spectrum of light emitted by that star.

The terminology used to describe a particular technique generally reflects one or more aspects of the type of energy analysed, the particles involved and the source of excitation which generates the output being analysed. In the case of the Alpha-Proton X-ray Spectrometer (APXS) this indicates the involvement of alpha particles, protons and X-rays.

How does Spectroscopy work?

At a practical level, spectroscopy is essentially about the measurement of energy levels, and then comparing those measured values to some known references values, determined by experiment or theory, which are fixed properties of elements, or atoms, or in some forms of spectroscopy, molecules. For example, take the element sodium (see Figure 1).

Sodium (atomic number 11, atomic mass 23) has a nucleus consisting of 11 protons and 23 - 11 = 12 neutrons, and hence 11 electrons in its non-ionised form (to be non-ionised there must the same number of negatively charged electrons as there are positively charged protons). The electrons are distributed in three shells - 2 in the inner shell, 8 in the next, and 1 in the outer. In its stable state, a sodium atom has certain amounts, or levels, of energy associated with the interactions of all these particles with each other. These levels are associated with properties such as the binding between the protons and neutrons, the repulsion between protons, the repulsion between electrons, the attraction between protons and electrons, the shielding of the outer electrons by the inner electrons, the sizes and distances between them all, and so on. If this balance is disturbed by adding energy to the atom, say by bombarding it with a high speed and/or charged particle, then for example one of the electrons might 'jump' to a higher shell. This is an unstable state so the electron will instantaneously 'fall back' to its original level, and as it does so it will emit exactly the same amount of energy it took to move the electron (or 'excite' it) in the first place, in the form of electromagnetic radiation. Because of all the properties mentioned above, this particular amount of energy is unique to the sodium atom, and the same is true for all elements.

Now suppose the particle which was bombarding the element consisted of protons and/or neutrons itself. If it had sufficient energy this particle might interact with the nucleus of the element it came into close proximity with, and if it did so a fixed amount of energy would again be emitted depending on the nature of the particles and the interaction involved. Take as an example here the nitrogen atom, atomic number 7 (see Figure 2).

The atomic number indicates that the nitrogen atom has 7 protons, and in its most common isotope has 7 neutrons associated with these protons in the nucleus. An alpha particle has two protons and two neutrons, and when nitrogen atoms are bombarded with alpha particles there are interactions which involve exchanges of certain amounts of energy and the emission of protons. More miraculous perhaps is the fact that when nitrogen does interact with an alpha particle a proton and neutron from the alpha particle become incorporated into the nitrogen nucleus which then is no longer a nitrogen atom nucleus but an oxygen atom nucleus since as we have seen the number of protons defines what an element is.

nitrogen nucleus + alpha particle ⇨
oxygen nucleus + proton + energy

So by knowing the different energy levels involved for these different types of interactions, the elements present in an unknown sample can be determined by examining the energy emitted when the sample is subjected to energy from an external source, a radioactive element perhaps.

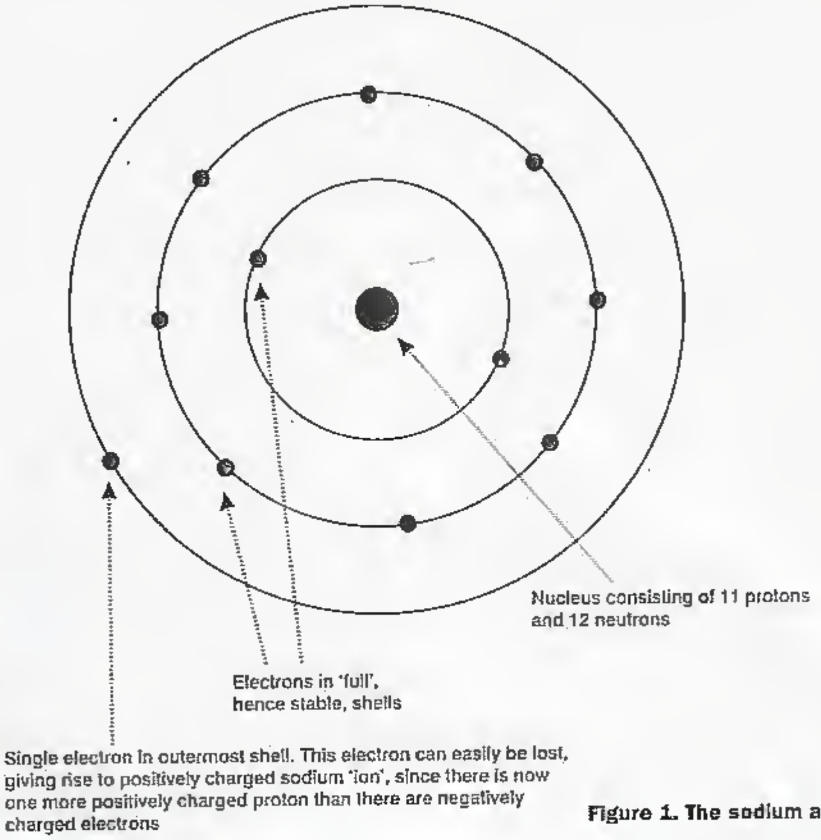
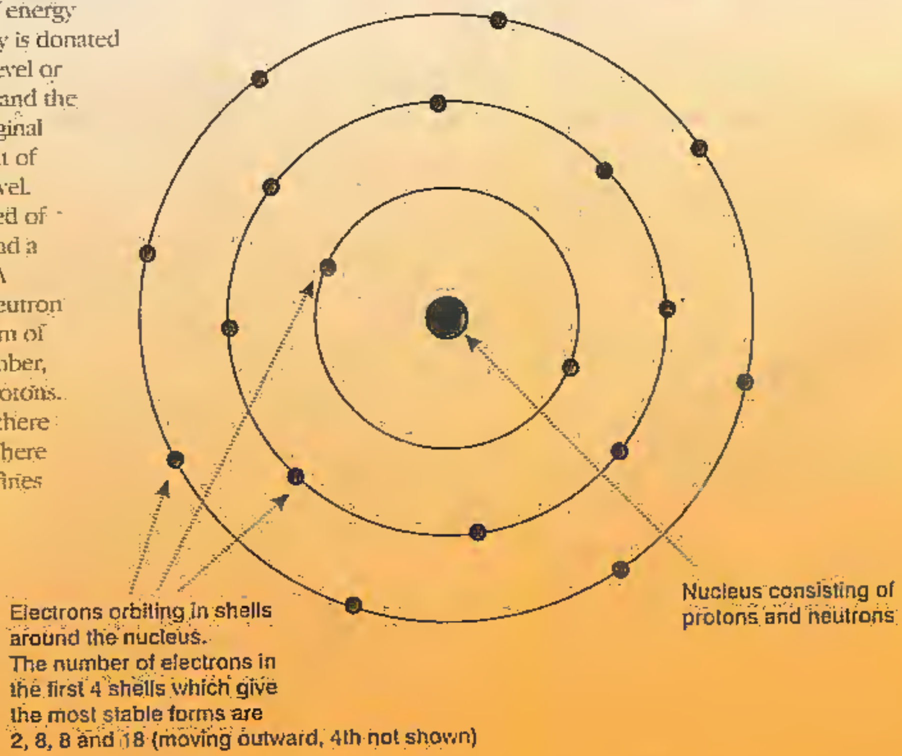

Nucleus consisting of 11 protons and 12 neutrons
Electrons in 'full', hence stable, shells
Single electron in outermost shell. This electron can easily be lost, giving rise to positively charged sodium 'ion', since there is now one more positively charged proton than there are negatively charged electrons

Figure 1. The sodium atom.

Inside The Atom

An atom can be considered to consist of a small core, called the nucleus, surrounded by electrons which orbit in 'shells' around the nucleus in much the same way as planets orbit the sun. The nucleus is extremely dense and comprises around 99.9 % of the mass of an atom, but only about one over ten to the power fourteen (one hundred million millionths) of the volume. There are only a few positions where the electron orbits can exist; these positions are at fixed 'heights' above the nucleus, and there is a maximum number of electrons for each orbit which each orbit can hold if the atom is to be stable. The 'height' of an electron above the nucleus is a measure of the amount of energy 'possessed' by the electron, and if enough energy is donated to the electron it will 'jump' to a higher energy level or orbit. This however will not be a stable situation and the electron will instantaneously drop back to its original level, at the same time emitting the same amount of energy it absorbed to reach the higher energy level.

The nucleus can be considered to be composed of protons and neutrons (a proton is 1836 times, and a neutron 1840 times, as massive as an electron). A proton has a single positive charge, whereas a neutron has no charge. The number of protons in an atom of an element is given by the element's atomic number, for example argon, atomic number 18, has 18 protons. An electron has a single negative charge and so there are as many electrons in an uncharged atom as there are protons. It is the number of protons that defines what an element is, but the number of neutrons in the nucleus of an element can vary depending on the stability of the particular configuration. The total number of protons plus neutrons is the mass number of an element; atoms of an element with different numbers of neutrons in the nucleus are called isotopes of the element. Argon has three stable isotopes (unstable isotopes undergo radioactive decay until a stable configuration is achieved) with eighteen, twenty and twenty two neutrons respectively; the three isotopes therefore have corresponding mass numbers of thirty six, thirty eight and forty. The different stable isotopes of an element occur naturally in varying proportions, and this is reflected in the atomic weight of an element which is effectively a weighted average of the atomic masses of the isotopes and hence not an integer. 99.6 % of argon is in the form of the isotope with mass number forty, and this is reflected in argon's atomic weight of 39.948.


Electrons orbiting in shells around the nucleus.
The number of electrons in the first 4 shells which give the most stable forms are 2, 8, 8 and 18 (moving outward, 4th not shown)
Nucleus consisting of protons and neutrons

Plotting a graph of these energy levels emitted provides a more easily understandable visualisation of the spectrum of energy output, and by comparing this spectrum with reference values information can be deduced about the sample material.

This then is the basic principle behind spectroscopy, so now we'll look at alpha particles, protons and X-rays before moving on to the principle of the Alpha-Proton X-ray Spectrometer (APXS) itself.

Alpha particles, Protons and X-rays

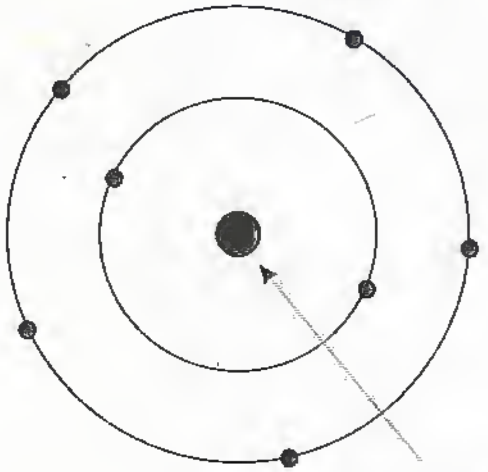
Alpha particles, protons and X-rays sound mysterious but in fact we already know what they are by knowing what an atom is, because they are the terms used to describe particular aspects of atoms and radiation. As we have seen, an alpha particle is simply a particle consisting of two protons and two neutrons, and can in fact be thought of in even simpler terms, since this is just a helium atom (atomic number 2) which has lost all (both!) of its electrons i.e. it is a helium nucleus. The reason it is of such importance is that it is a very stable configuration, and is one of the particles that is emitted when one type of radioactive decay occurs. When this type of decay occurs then the remaining element has two less protons and two less neutrons i.e. it transmutes into something else. Hence for example uranium (atomic number 92) decays to thorium (90), which itself decays to radium (88), which then decays to radon (86), which in turn decays to polonium (84) which finally decays to lead (82) which is stable, ie:

uranium ⇨ thorium + alpha particle
thorium ⇨ radium + alpha particle
radium ⇨ radon + alpha particle
radon ⇨ polonium + alpha particle
polonium ⇨ lead + alpha particle

Similarly, a proton is a simply a hydrogen atom (atomic number 1) with its solitary electron removed, ie it is a hydrogen nucleus, and so along with the neutron is one of the elementary particles which compose all elements. (See Figure 3.)

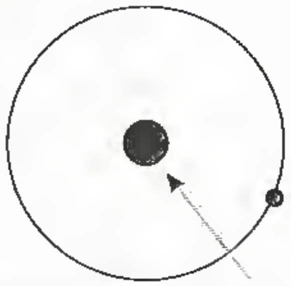
Unlike alpha particles and protons which are of course particles, X-rays are a form of electromagnetic radiation. Electromagnetic radiation is defined as a disturbance in the electric and magnetic fields around the body that produces it, and is generated when an electron accelerates, i.e. speeds up or slows down. So when an electron jumps from one shell to another in an atom, and then falls back, it is accelerating and so generates electromagnetic radiation (see Figure 4).

The speed at which it moves from shell to shell is dependent on the energy levels involved, and the speed at which it moves defines the frequency of that radiation, ie the frequency is a measure of the energy. Electromagnetic radiation occurs at frequencies ranging from tens of hertz to beyond ten raised to the power 25 (1 followed by twenty five zeros) Hertz, and this spread is divided into variously named



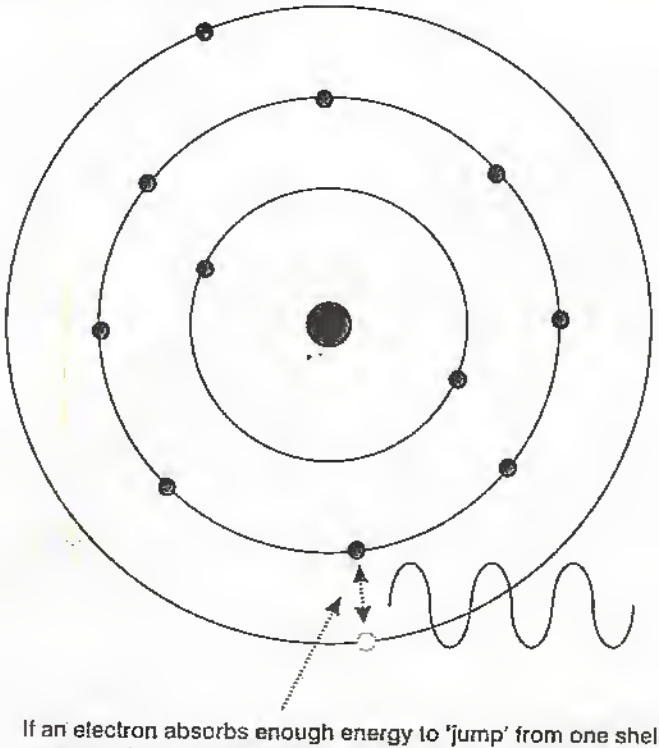
Nucleus consisting of 7 protons and 7 neutrons in the most common form. A second isotope of nitrogen has an extra neutron.

Figure 2. The nitrogen atom.



Nucleus consisting solely of 1proton - if the atom is stripped of its only electron a free elemental proton particle remains.

Figure 3. The hydrogen atom.



If an electron absorbs enough energy to 'jump' from one shell, or energy level to another, it will 'fall back' to its original level, emitting energy at a frequency which is a measure of that energy.

Figure 4. Emission of electromagnetic radiation due to electron transistions.

ranges such as radio waves, visible light and gamma rays. X-rays are simply part of this spectrum of frequencies and as such cover the frequency spectrum of approximately ten to the power sixteen to ten to the power twenty Hertz (see Figure 5).

Alpha-Proton X-ray Spectrophotometry (APXS)

APXS, as the name implies, analyses material by subjecting it to alpha particles from a radioactive source. Under this bombardment 'light' elements ('lightness' referring to atomic number, and in this case meaning those up to about silicon, atomic number 14) emit protons, or positively charged hydrogen atoms. These include carbon, nitrogen and oxygen which are the elements making up organic compounds, the indicators of possibly living material.

'Heavier' elements, in this case heavier than sodium, atomic number 11, emit X-rays as a result of ionisation caused by the bombardment. Rocks, soils and minerals are composed of these elements and their composition gives an indication of the processes involved in their formation e.g. perhaps volcanic.

Each 'event', or interaction, causes the emission of a 'pulse' of a particular level of energy. So by using detectors which measure the number and energy levels of these pulses a graph can be plotted which shows peaks at energy levels corresponding to particular elements, and the heights of these peaks indicate the relative abundance of the elements and hence the elemental composition of the material under analysis. (see Figure 6.)

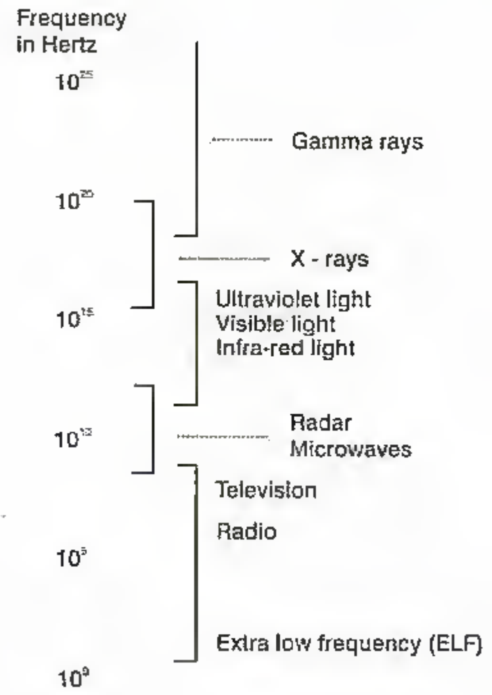


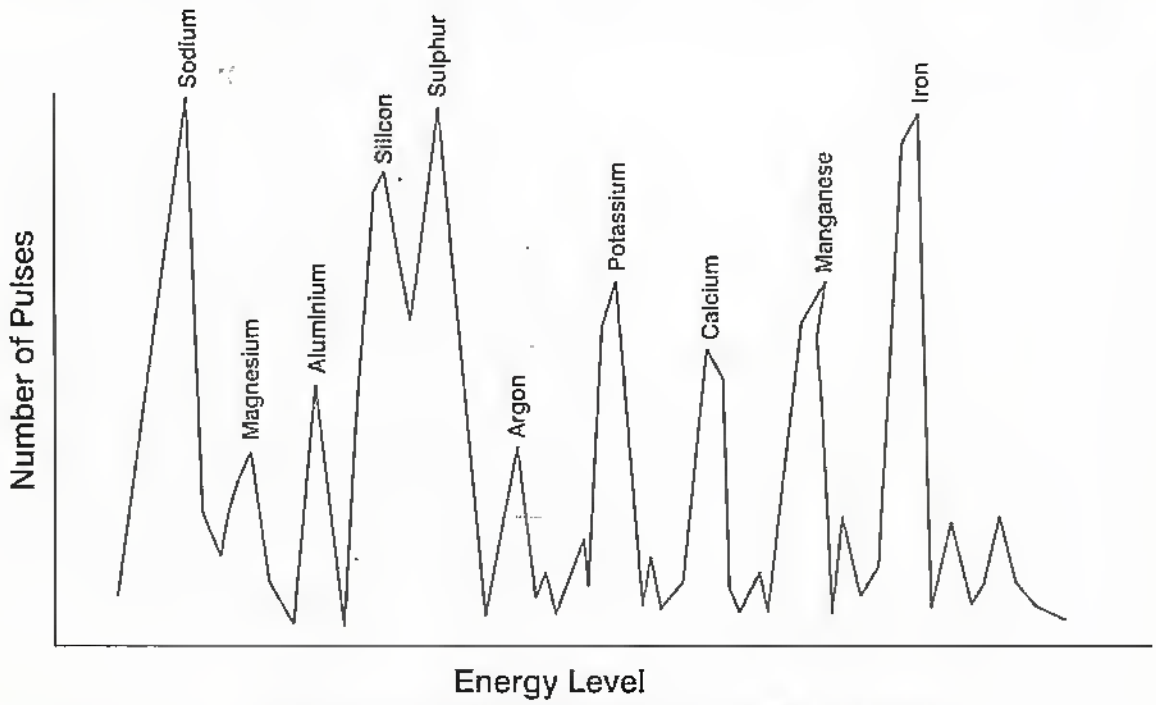
Figure 5. The electromagnetic radiation spectrum.

Newton's Rainbow

The techniques which come under the broad heading of spectroscopy are now used for the analysis of the constituents of material found throughout the universe. Isaac Newton in the seventeenth century is the person credited with first recognising the significance of what he saw when he passed a ray of sunlight through a prism and showed that it was composed of many colours. Little did he know when he called this spread of radiation a 'spectrum' that he was naming not only a range of colours but also a range of techniques which would enable us to deduce the composition of distant stars without leaving the laboratory, and to take science on a journey not only into the atom but also to Mars and beyond.

Acknowledgements:

Encyclopaedia Brittanica CD-ROM
Electronics and Beyond November 1998

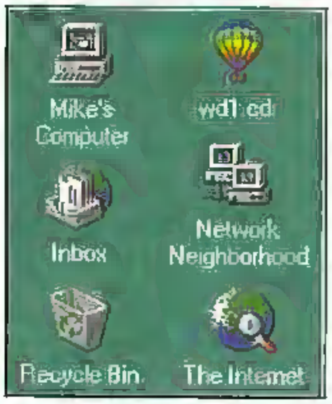


Energy levels along the x-axis correspond to known characteristics X-ray energies generated due to ionisation - thus each peak can be identified as being due to a particular element. The number of pulses plotted along the y-axis corresponds to the abundance of the element in the sample.

Figure 6. A hypothetical spectrum.

Software HINTS & TIPS

If you started on PCs before Windows 95 you might not be using your system to the full. Mike Bedford shows you how to make the most of the desktop.



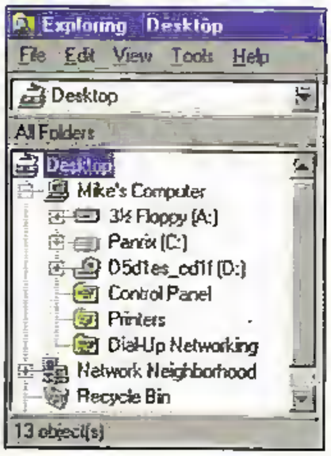
The nature of software is such that it's difficult to write a column like this confident that the information presented will be new to virtually all readers. Without a doubt many of you make full use of the Windows 95 or 98 desktop. But since there are lots of ways of doing things, other people – mainly those who have graduated from an earlier version of Windows – may not be aware of how powerful this facility is. Using the desktop won't allow you to do things that can't be done in other ways but it could make you more productive. Others may simply decide that it's a more intuitive interface.

Try it Out

The Windows 95 or 98 desktop is the background which you'll see if you're not displaying full screen windows. By default it's turquoise but, as we saw in an earlier column, you can change its colour or define a pattern. But it's far more than just a fancy looking screen background. The easiest way to get a feel for the desktop is to try some things out. So to start out, open the Windows Explorer, make sure it doesn't occupy the full screen, select a data file (e.g. a word processor or graphics file), hold down the Ctrl key and drag that file off the Windows Explorer window onto the desktop. You'll find that you end up with an icon for that file on the desktop but the original file will also be in its original folder. And just as with normal operations in Windows Explorer, if you hadn't held down the Ctrl key then you'd have moved the file to the desktop rather than just putting a copy of it there. In the following screen shot I've dragged a copy of the file wd1.cdr onto the desktop and you'll notice that it appears alongside the various icons which were already on the desktop.

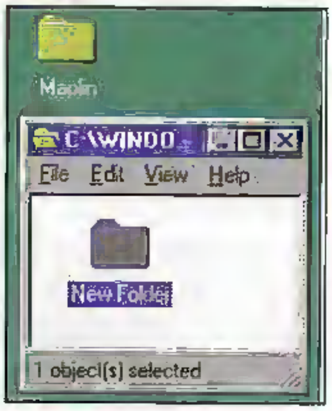
As you might expect, so long as the file has an application associated with it, then double clicking on the icon will open that file in the appropriate application. In the case of my file, double clicking on the icon opens it in Corel Draw! Try it on your file. The desktop is, therefore, a useful place to put files which you're going to access frequently – it's much easier to open a file here than to find it in the hierarchical file system. Clearly, though, it doesn't make sense to keep too many files here at any one time – needles and haystacks come to mind.

I'm sure that a number of readers will already be trying to figure out exactly where files on the desktop are stored. Certainly these must actually be stored on the hard disk somewhere but I suggest that you view the desktop in conceptual terms only. Viewed this way, the desktop is not a part of the hard disk, in fact it's not even part of the local computer, it's at a higher level than this as the following Windows Explorer screen portion will prove.



Desktop Folders

Having just suggested that you don't keep many files on the desktop, if you really want to, you can organise the desktop as hierarchical folders just like the hard disk although, personally, I think this defeats the object. However, do try it out and if you find it useful then use it. Find a blank area of the desktop and click right. From the menu which is displayed select New > Folder. A folder with the default name New Folder is created on the desktop and you can change this to a more meaningful name just as you would in Windows Explorer. In fact, if you really want to find out where Windows stores desktop documents, double click on the folder icon to open the folder and you'll find that it's actually stored in C:\WINDOWS\DESKTOP\ (although this folder is hidden by default in the Windows Explorer). Furthermore you can right click in this window to create folders within that folder ad infinitum.



A Clipboard

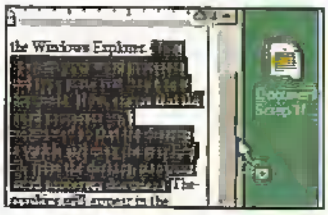
The desktop can also be used as a sort of clipboard. Let's see how this works. First of all, copy a small graphics file (in a format supported by your word processor) to the desktop using the Windows Explorer. Now open up your word processor and type some text into a new document. Now, ensure that the word processor isn't maximised so that the desktop is visible and drag the graphics file from the desktop into your word processor document. The graphics will appear in the document at the position you release the mouse button. You can also do this in reverse. Try highlighting an area of text in your word processor document and dragging it onto the desktop. A new 'scrap' file will be created on the desktop containing the selected text. Clearly this can now be dragged into another document. This also works with spreadsheets, graphics software, in fact just about any application.

Shortcuts

The other type of object you can place on the desktop are short-cuts to programs or files. In fact, you probably already have some short-cuts on your desktop since this is the way some applications are installed. A short-cut is an icon which allows you to start an application or open a file more easily than finding it in the Start menu or from the disk. A short-cut is not a copy of a file or application though – we've already seen how to create these on the desktop – it's purely a way of accessing a file which is stored elsewhere. As with data files, though, it only makes sense to put a few short-cuts on your desktop. If you have too many, it will prove harder to find them on the desktop than by other methods.

To create a shortcut, find the file using the Windows Explorer, select it and copy. Now move the mouse pointer over the desktop, right click and select Paste Shortcut from the menu which is displayed.

And finally, anything on the desktop – i.e. a file or a short-cut - can be deleted (or moved to the waste basket) by selecting it and pressing Shift Delete (or just Delete to put it in the wastebasket).

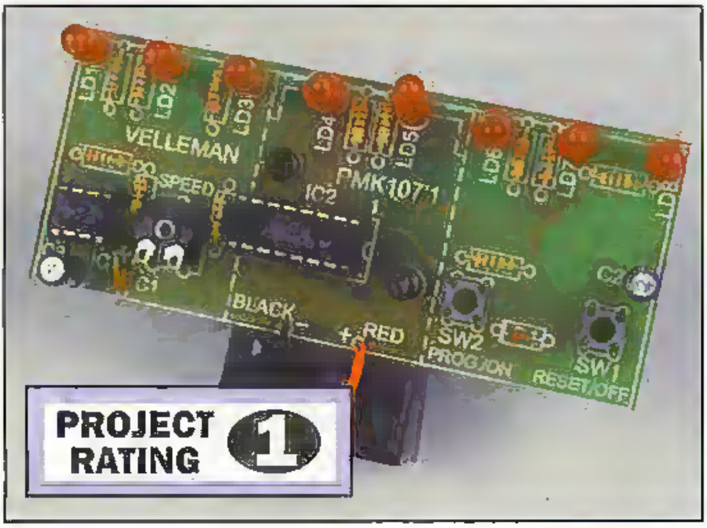


Velleman Kits – LED RUNNING LIGHT & SIGNAL GENERATOR

This month John Mosely constructs two kits from the Velleman 'Minikits' series.

The Velleman Mini-kits are not just an excellent introduction to electronics for the beginner, but also provide some 'light relief' to the more experienced constructor, or can be adapted for more novel applications. All are inexpensive - costing less than a fiver, and include all the main components, except the battery and enclosure. I have put together several of them now - each one can be constructed in less than an hour - and all work very well.

Each kit is packed in a small clear plastic 'box' that are stapled to a thick folded card. It is worth remembering that the card has the instructions and circuit diagram printed on it , so be very careful when removing the packaging. Being someone who's eyesight is not what is use to be, the circuit diagram is rather small, making reading values a little difficult. However, overcoming this problem is relatively easy and following the construction diagram soon produces a working module.



PROJECT RATING 1

Construction

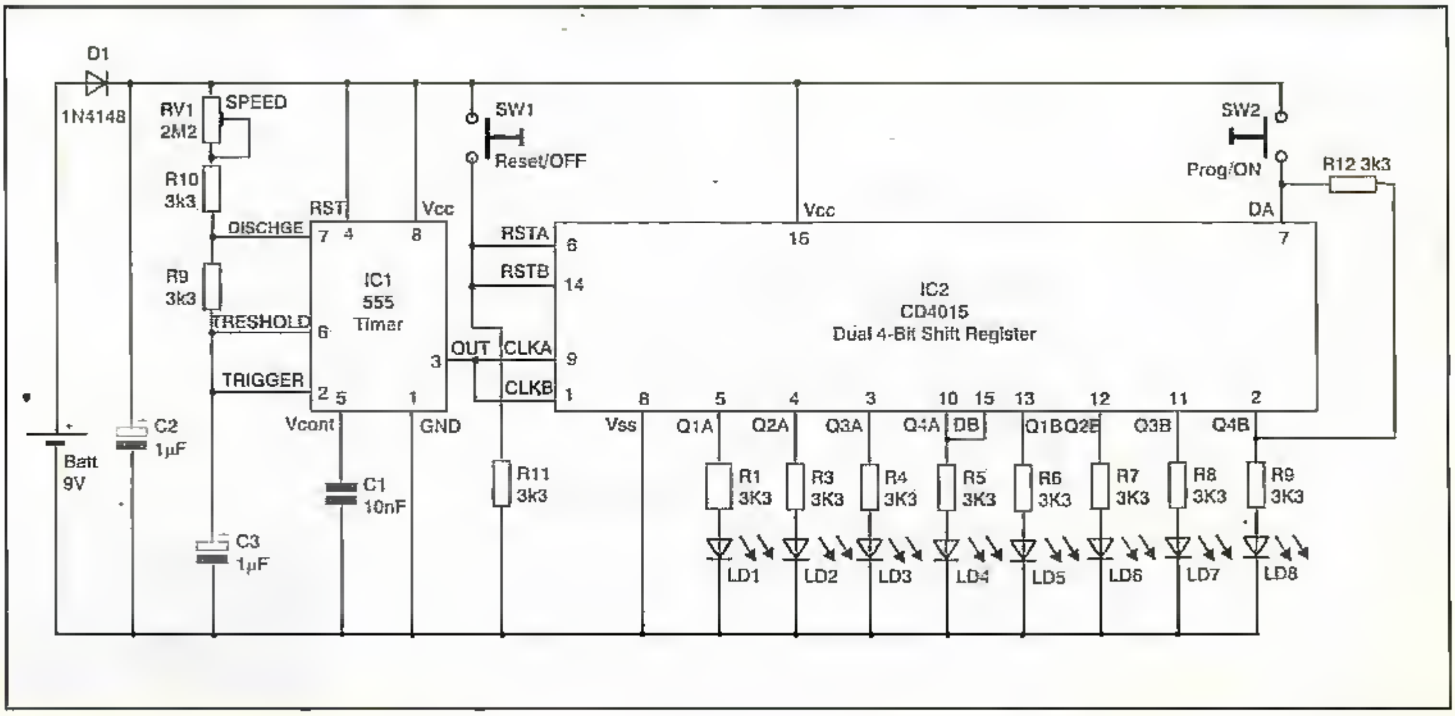
Construction is very straight forward, and in general starts with the small components - resistors, diodes, capacitors, transistors, electrolytics, LEDs, DIL IC sockets, switches etc. Insertion of the ICs, if any, is left to last. Most of the kits require a 9V PP3 battery (not supplied) power supply, and a suitable battery holder is included that conveniently screws to the PCB. To date, I have required no test equipment to set up the finished kits.

LED RUNNING LIGHT PARTS LIST

RESISTORS	
R1 - 12	3k3 Min Res
RV1	2M2 Horiz Preset
CAPACITORS	
C1	10nF
C2, 3	1µF PC Elect
SEMICONDUCTORS	
D1	1N4148
IC1	555 Timer
IC2	CD4015 Dual 4-bit Shift Reg
LD1 - 8	Red LED Low Current

MISCELLANEOUS	
SW1, 2	Single Pole Push Sw
Batt	9V PP3
	Battery Holder
	16-pin DIL Socket
	8-pin DIL Socket
	PCB

ORDER CODE	PRICE INC. VAT
VX96E	£4.99

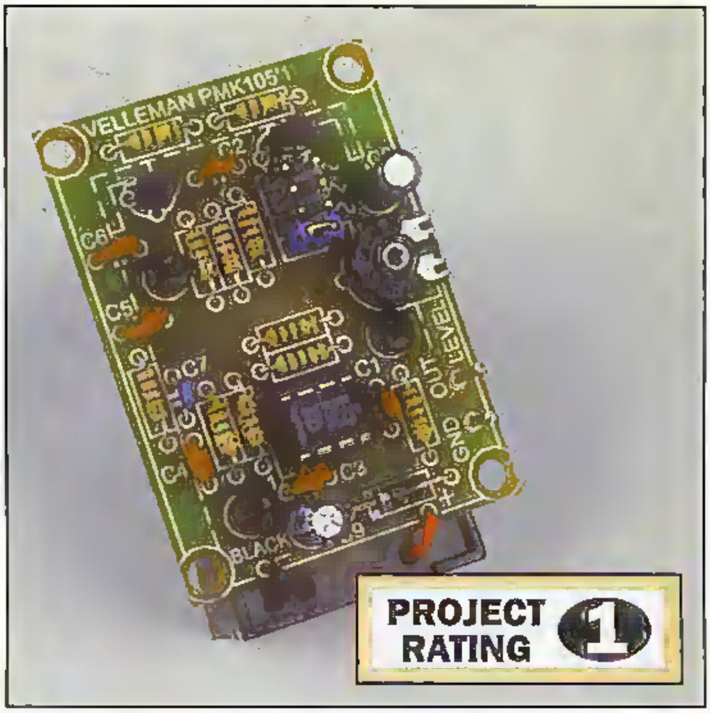


LED Running Light

The circuit is very straightforward and uses a 555 timer that clocks a 4015 dual 4-bit shift register. D1 provides protection from inadvertent reverse connection to a battery supply. Ray Marston in his excellent article LED Chaser & Sequencer Circuits (December 1998 issue 132) explains the operation of similar types of circuits. RV1 is used to adjust the speed of the lighting effect. SW1 and SW2 are small push-to-make switches that turn-off/reset the circuit (SW1) and turn-on and programme the effects. The first push causes one LED to light and progress from left to right, and continually pressing increases the number on to two, then three etc. again moving from left to right. A point is reached when all LEDs will be on. Although on the supplied PCB all the LEDs are in a straight line, there is no reason why the LEDs cannot be placed remotely (to a small box), and arranged in any desired shape.

It is important to observe correct polarity of the diode, electrolytics and LEDs, and the board legend clearly indicates correct polarity. As always, please check your handiwork for shorts, dry joints etc. A few minutes carefully checking the board can save a lot of time and heartache.

The final result produces pleasing results. The LEDs are bright and the unit consumes very little power. I had the display on for several hours and the battery was still going strong.



PROJECT RATING 1

SPECIFICATION

Output waveform: sine, square, triangle, integrator
Frequency: 1kHz fixed
Output level: 0 to 200mV rms
Power supply: 9V

SIMPLE SIGNAL GENERATOR PARTS LIST

RESISTORS	
R1, 2, 3	1k Min Res
R4, 5, 6	10k Min Res
R7	15k Min Res
R8	4k7 Min Res
R9, 10	100k Min Res
R11	1M Min Res
RV1	47k Preset

CAPACITORS	
C1, 2	10nF
C3, 4, 5, 6	47nF
C7	100nF
C8, 9	1µF PC Elect

SEMICONDUCTORS	
D1	1N4007
TR1, 2	BC547B
IC1	555 Timer

MISCELLANEOUS	
Batt	9V PP3 Battery
	Battery Holder
	8-pin DIL Socket

ORDER CODE	PRICE INC. VAT
VX94C	£4.99

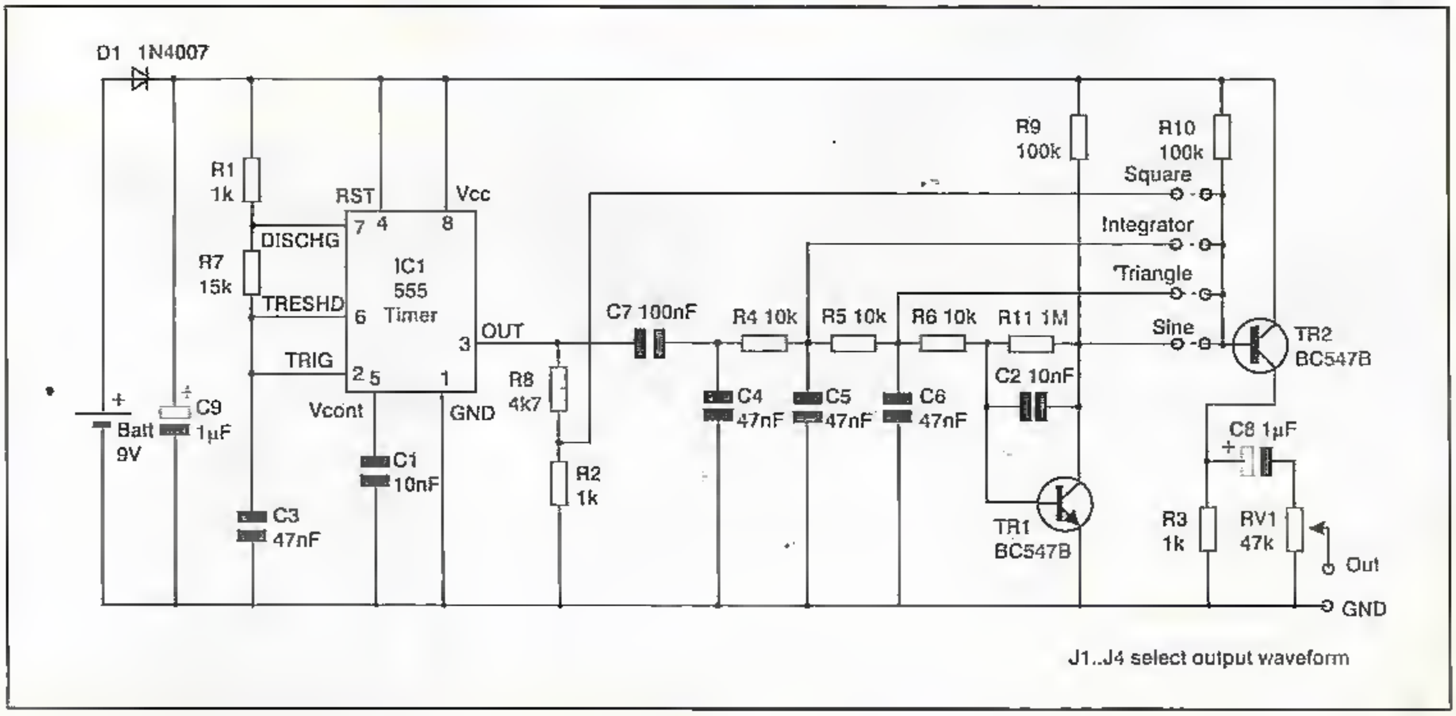
Signal Generator

This is a very simple circuit that again uses a 555 timer set at 1KHz, which produces a square wave output. It can then be shaped to produce either a 'square,' 'integrator,' 'triangle' or 'sine' wave output. A small jumper is used to select the desired output waveform. RV1 provides a variable output level to inject in to a circuit. This output could be attached to a suitable probe if so desired, with an earthing connection via a length of wire and a crocodile clip.

Again construction is very straightforward, and took less than an hour. This project can easily be mounted in to a small plastic box with a probe attached. The little jumper that is used to select the output waveform could be replaced by a small rotary switch or slide switch. This would depend on your choice if you wanted all the available output waveforms. Similarly, the positive battery lead could be routed via a small push-to-make switch, or a small single-pole, single-throw type switch. The battery should last for many months before it needs replacing.

I checked the waveforms on an oscilloscope, especially the sine wave, for distortion, purity etc., and found the waveforms to be exceptionally good at 1kHz as claimed. The variable output level produced a maximum output of 400mV pk-pk.

This is an excellent little kit, that not only is easy to make, but is a very practical one too.



Diary Dates

Every possible effort has been made to ensure that information presented here is correct prior to publication. To avoid disappointment due to late changes or amendments, please contact event organisations to confirm details.

April 1999

1 April. Internet Seminar, Star, Legoland, Windsor. Tel: (01285) 884422.

3 to 18 April Edinburgh International Science Festival, Edinburgh. Tel: (0131) 220 6220.

13 to 15 April NEPCON Electronics, NEC, Birmingham. Tel: (0181) 910 7910.

20 to 21 April Intranet EXPO 1999, Earls Court, London. Tel: (0181) 742 2828.

May 1999

6 May. Internet Seminar, Star, Birmingham. Tel: (01285) 884422.

17 to 19 May Cable & Satellite Mediacast 1999, Earls Court, London. Tel: (0181) 910 7931.

25 to 27 May Internet World UK Spring 1999, Earls Court, London. Tel: 0171 976 0405.

25 to 28 May Ninth International Conference on Metering and Tariffs for Energy Supply International, IEE, Conference Centre, Birmingham. Tel: (0171) 240 1871.

26 to 27 May Embedded Systems, Olympia, London. Tel: (0171) 681 1000.

June 1999

7 to 11 June. 16th International Teletraffic Congress, IEE, Edinburgh International Conference Centre. Tel: (0171) 240 1871.

8 June. Internet Seminar, Star, London. Tel: (01285) 884422.

8 to 10 June. Environmental Technology Show, NEC, Birmingham. Tel: (0181) 910 7732.

21 to 23 June. People in Control an International Conference on Human Interfaces in Control Rooms, Cockpits and Command Centres, IEE, University of Bath. Tel: (0171) 240 1871.

12 to 15 June. Seventh International Conference on Image Processing and its Applications, Manchester. Tel: (0171) 240 1871.

29 June to 1 July. Networks Telecom, National Exhibition Centre, Birmingham. Tel: (0181) 742 2828.

30 June to 4 July. BBC Tomorrow's World Live, Earls Court, London. Tel: (0171) 402 2555.

July 1999

6 July. Internet Seminar, Star, Old Trafford, Manchester. Tel: (01285) 884422.

26 to 28 July. Third International Conference on Advanced A/D and D/A Conversion Techniques and their Applications, University of Strathclyde, Glasgow. Tel: (0171) 240 1871.

August 1999

10 Aug. Internet Seminar, Star, Edinburgh. Tel: (01285) 884422.

23 to 27 Aug. Eleventh International Symposium on High-Voltage Engineering, London. Tel: (0171) 240 1871.

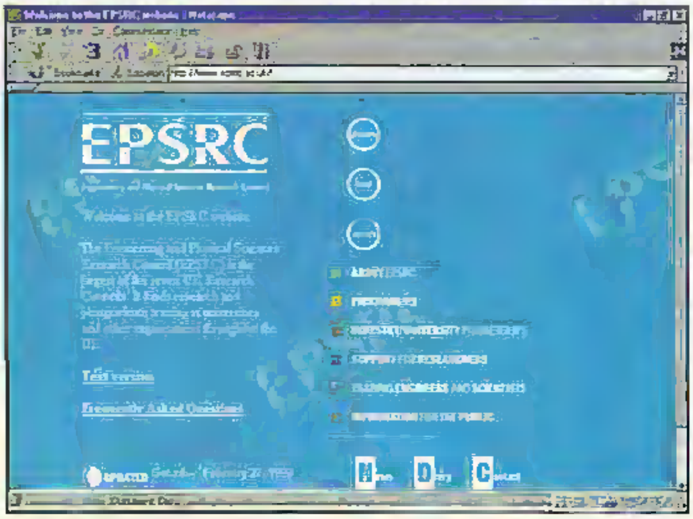
September 1999

1 to 3 September Ninth International Conference on Electrical Machines and Drives, Canterbury Christ Church College. Tel: (0171) 240 1871.

7 to 10 September Ninth International Conference on Artificial Neural Networks, IEE Conference on Artificial Neural Networks, University of Edinburgh. Tel: (0171) 240 1871.

Please send details of events for inclusion in 'Diary Dates' to: News Editor, *Electronics and Beyond*, P.O. Box 777, Rayleigh, Essex SS6 8LU or e-mail to swaddington@cix.compulink.co.uk.

What's On?



Going Solar Together

What do Newcastle United's football stadium, the Earth Centre near Doncaster, and the Equinox office building in West London have in common?

Answer. They are all buildings planning to use solar energy installations to provide them with clean electricity. They are also typical of projects on which energy minister John Battle asked for Government and industry to work together speaking at the DTI/Engineering and Physical Sciences Research Council (EPSRC) Photovoltaics Conference in Manchester at the beginning of February.

Speaking at the conference, Battle said, "Solar energy has real potential, and I want Government and industry to join forces to develop its long-term future. This is why I am asking for the industry's involvement in taking forward three major new initiatives in the field of photovoltaics.

"The first project is a field trial for around 100 homes across the country, to test a variety of actual photovoltaics installations under real conditions. This would help us explore options and pave the way for a possible larger programme in the future. The project will look at the size of systems, types of building, and different technologies. A design manual for house builders is one of the aims of the project.

"The second initiative is a call for proposals for the development of photovoltaic components and systems, with the aim of enhancing the competitiveness of UK companies. Projects could expect to receive between 25% and 50% of the total cost from a budget of £1 million. Preference would be given to projects involving collaboration between companies, and so take advantage of the widest sources of expertise.

"Potential projects could include applications with export potential, especially for developing countries. These could include water treatment, communications, refrigeration, healthcare and solar home systems. Applications could also include building integrated products and services - for example, multi-functional roofing and cladding products, or tools which help in the design, implementation or operation of photovoltaics systems; balance of systems components, such as energy storage systems, wiring and connections systems; and manufacturing processes."

Battle continued, "The third scheme would develop showcases for UK technology and design by demonstrating the use of photovoltaics in large-scale building applications, and to establish best practice for the future. I would like to see proposals from as wide a range as possible - commercial offices, large retail outlets, hospitals, leisure centres, or large housing estates. I hope we can fund five or six installations a year, including a proportion of the capital costs as well as the design, monitoring and evaluation of each project.

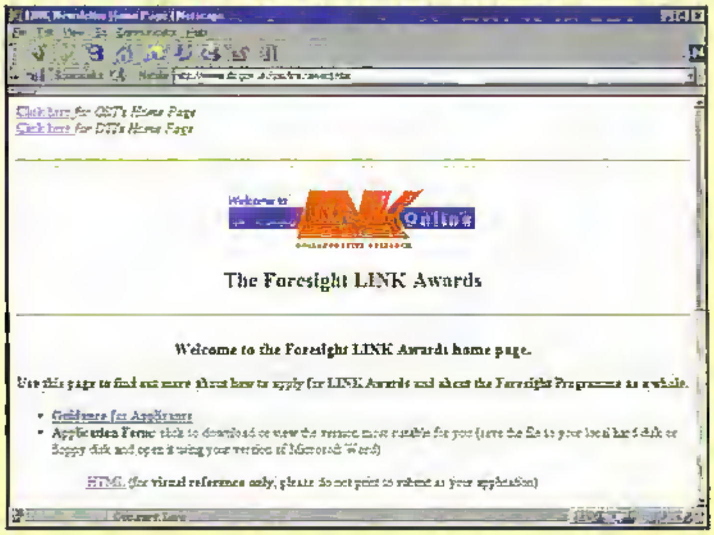
"This industry has come a long way already, and it has a great future ahead of it. I am determined to support the industry so that it can take its place in this Government's drive for more energy from renewable resources."

The three proposed initiatives are currently at planning stage, and comments from the photovoltaic industry are being sought on the detail of the schemes. Application procedures for the initiatives will be announced at a later date.

For further details, check: `<www.epsrc.ac.uk>`. Contact: DTI, Tel: 01793 444000.

£10 Million For Business/ Science Partnerships

Lord Sainsbury, the UK government minister for science, has announced £10 million of new funding available through the second round of Foresight LINK Awards.



Click here for OST's Home Page
Click here for DTI's Home Page

The Foresight LINK Awards

Welcome to the Foresight LINK Awards home page.

Use this page to find out more about how to apply for LINK Awards and about the Foresight Programme as a whole.

- Guidance for Applicants
- Application Form

HTML (for visual reference only, please do not print to submit as your application)

The funding will go towards projects that explore new market and technology opportunities in areas identified by Foresight as important to the future competitiveness and quality of life of the UK.

The principal thrust of applications for Awards must be innovative, high quality, pre-competitive research in areas of commercial potential. All such applications which address Foresight priority areas not covered by currently open LINK programmes - which the Awards are intended to complement - will be welcomed and given full consideration.

Small and medium-sized businesses are particularly encouraged to play an active part in applications, as are businesses in sectors that do not have an established track record of working with the science base. Further information on the Awards is available on the Foresight LINK Awards Web site.

For further details, check: `<www.dti.gov.uk/ost/link/award.htm>`.

Contact: DTI, Tel: (01793) 444000.

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Jobs to Kick Off Apple Developer Conference

Steve Jobs, Apple's interim CEO, will deliver the kick off keynote on the first day of Apple's 1999 Worldwide Developer Conference (WWDC), to be held on May 10 to 14 at the San Jose Convention Centre in San Jose, California, US.

Jobs will be joined by Avie Tevanian, Apple's Senior Vice President of Software Engineering, and together they will give developers an overview of Apple's software roadmap, including the first in-depth look at Mac OS X, Apple's next generation operating system.

The WWDC will include technical tracks on Mac OS, Mac OS X, Carbon, the Internet, Java, QuickTime, AppleScript, ColorSync, WebObjects, Universal Serial Bus (USB), FireWire and AltiVec.

For the first time, the conference will feature special sessions for Adobe Photoshop and QuarkXPress plug-in developers, there will also be business presentations outlining Apple's marketing programmes and sales strategies.

A computer in the PALM OF YOUR HAND

An affordable mobile office from Phenom

Now here is a palmtop computer that is of great value. Right now for only £299 from Maplin Electronics, you can get equipped with the 'office on the road'. This little devil will give you all the normal Windows CE packages including Word, Excel and Powerpoint. When your work is done, the urgent letters and reports can be E-mailed via a nearby phone line using the PCMCIA 33.6K modem that comes with the package. The alternative is to keep the information and when back at base you can download all those valuable reports, letters and spreadsheets on to your desktop PC via a cable docking station and link software. The inbuilt web browser also gives you the potential to surf the Internet.

The mono screen with optional backlight is touch sensitive and operates very easily using the provided stylus. This can speed up operations along with auto document recall when first opening up.

It has even got the facility to present your Power Point slide presentations via an external colour monitor. Estimated battery lifetime is 11 hours on a single charge.

Package includes FREE docking station
All at the bargain Package Price of £299-99 inc VAT
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MOTOROLA
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SPECIFICATION

- ◆ Windows 95/98 compatible
- ◆ 8Mb RAM
- ◆ 80MHz processor
- ◆ 640 x 240 Display
- ◆ Type II PCMCIA Slot
- ◆ Rechargeable Lithium or AA batteries
- ◆ 33.6K PCMCIA Modem

Photo 1. The famous Hubble space telescope photograph of stars forming in the Eagle Nebula, some 7000 light years away (Courtesy NASA STSCI).

Towards A THEORY OF EVERYTHING

Douglas Clarkson delves into the universe, particle physics, and life!

It is certainly very pleasant to write in the year 1999, very much aware that at the height of the Cold War, there was reason to doubt if we would survive collectively at all. Indeed it is perhaps a worth while reflection that some aspects of the Millennium Bug originate from the element of doubt regarding the survival of civilisation to the year 2000 - as if the resolution of such problems should not be taken too seriously.

Science in the twentieth century, while creating weapons of mass destruction, has been highly successful in rolling back the boundaries of knowledge to the ends of the known physical universe and also to the very fabric of matter itself. It is a paradox indeed that both approaches are looking to provide a better understanding of the way everything fits together in the physical world. In terms of a theory of everything, systems at the extremes of scale have to be reconciled. The process dynamics that triggered the whole of the physical universe into existence and determine its ultimate fate is being investigated by the largest computers on the planet, and the most powerful particle accelerators working and soon to be working.

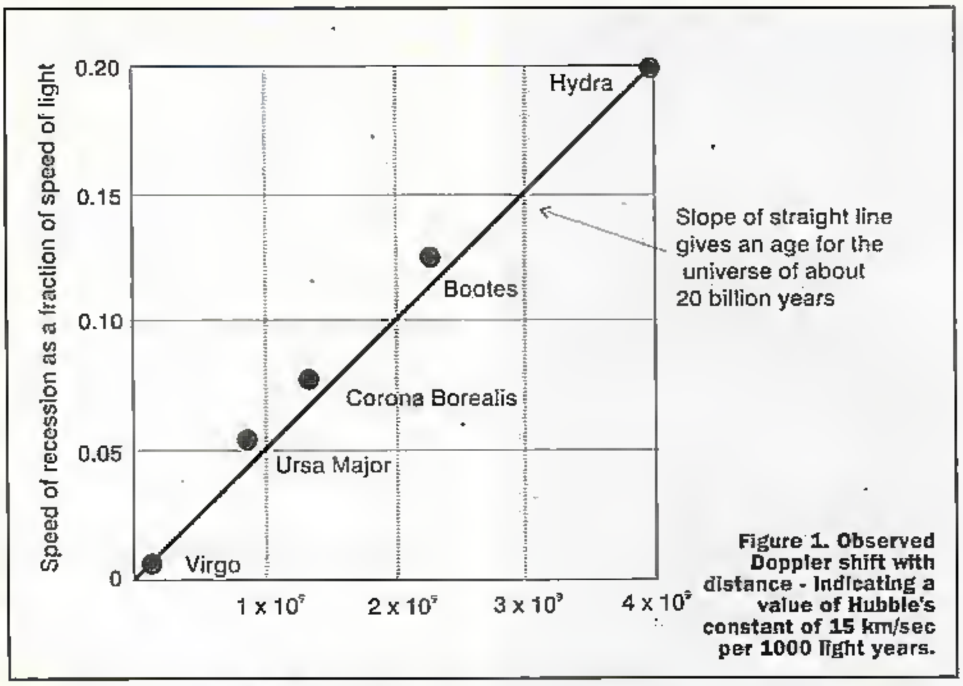


Figure 1. Observed Doppler shift with distance - indicating a value of Hubble's constant of 15 km/sec per 1000 light years.

Sharing the Mysteries of Science

Questions of the origin of the Universe have entered the mainstream of everyday thinking - as was made evident by the popularity of Steven Hawkins's book 'A Brief History of Time' which between its first edition in 1988 and my copy of 1992 has been reprinted no less than 27 times. Indeed the publication of this title was to see the emergence of a whole new strata of 'Popular Science' publishing which would deal with an expanding range of topics including Cosmology, Genetics and Chaos Theory. One of the successes of Steven Hawkins books was the ability of the author to formulate questions within the text which aroused the curiosity of the reader. Not all of the questions, however, thus raised could be answered. This did not detract from the success of the book. In fact this must be seen as one of the essentials for progressive science that it must constantly be asking itself questions. There is also something important about scientists communicating their understanding to the public since it is the public, through the mechanism of taxation which funds major programmes of particle physics research.

One of the problems with modern society is that science is perceived as principally one of providing answers - answers to everything - giving the impression that eventually there will be no questions to answer. In so doing, the mystery of the unknown is consequently diminished. One of the perplexing developments in society has been the loss of the sense of mystery of everything. Science may have given us lots of answers but it is not the role of science to give the impression that there remain no mysteries.

Some Big Questions

The mind of the scientist has, however, expanded in various fields in relation to looking at the bigger issues, rather than becoming completely bogged down with everyday laboratory physics - interesting as such studies may well be. As increasing confidence is placed in the Big Bang theory which considers that the Universe expanded from an incredibly hot nucleus, so there is now speculation about 'when the clock struck zero' or even 'before the clock struck zero'. Also, since everything that happens to us in our daily life hopefully can be assigned a reason, scientists are beginning also to ask - 'Why did the Big Bang take place?' A more correct description, however, of the theory of the origin of Creation is the 'Standard Model'. This is perhaps not a very exciting expression. Even when we go shopping, we try to avoid having to buy a 'standard model' of anything.

Also, as scientists discover the basic laws of matter, the basic building blocks of particles and ways of association are determined, questions are also being asked about the precise set of rules that ensure the stability of the physical universe. Is there some basic process of selection at play in the way, for example, that atoms when created allow organic molecules to exist? What are the rules that cause protons, neutrons and electrons to exist as they do? So we see that science is making discoveries and also asking 'Why is it like this'?

This aspect of the rules of the game is described in terms of either the 'weak anthropic' principle or the 'strong anthropic' principle. A more fundamental aspect of such analysis relates to the very process of expansion of the Universe which has been determined to be very sensitive to minute variations of interactions of energy and matter and which with the 'wrong' values could have resulted in a 'damp squib' rather than the grand 'roller coaster' of an event that we are led to believe took place 'when the clock struck zero'. Recent photographs of the Hubble Space telescope reveal the shear magnitude of the process of creation of stars and associated planetary systems. Photo 1 shows the famous photograph of stars forming in the Eagle Nebula, some 7000 light years away.

So science has therefore progressed from merely determining the laws of physics to assessing them in the light of possible permutations of all the laws that could possibly have come into existence. This is like some codebreaker trying to assess the psychology of the person setting the codes. Some theorists can even conceive of parallel physical universes that relate to different solutions of the basic cosmic equations. While at the beginning of the century, physical science was diminishing the potential for the existence of God in the Universe, by explaining in an apparently increasingly mechanistic world, there is also a more creative, inquisitive scientific

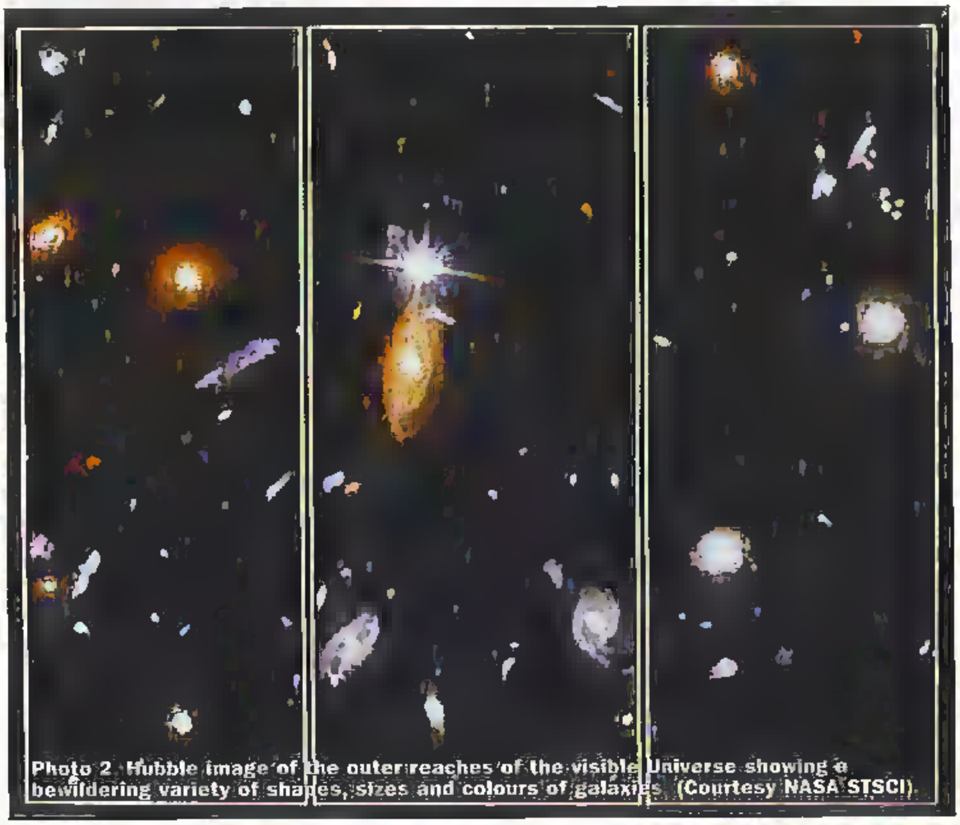


Photo 2. Hubble image of the outer reaches of the visible Universe showing a bewildering variety of shapes, sizes and colours of galaxies. (Courtesy NASA STSCI).

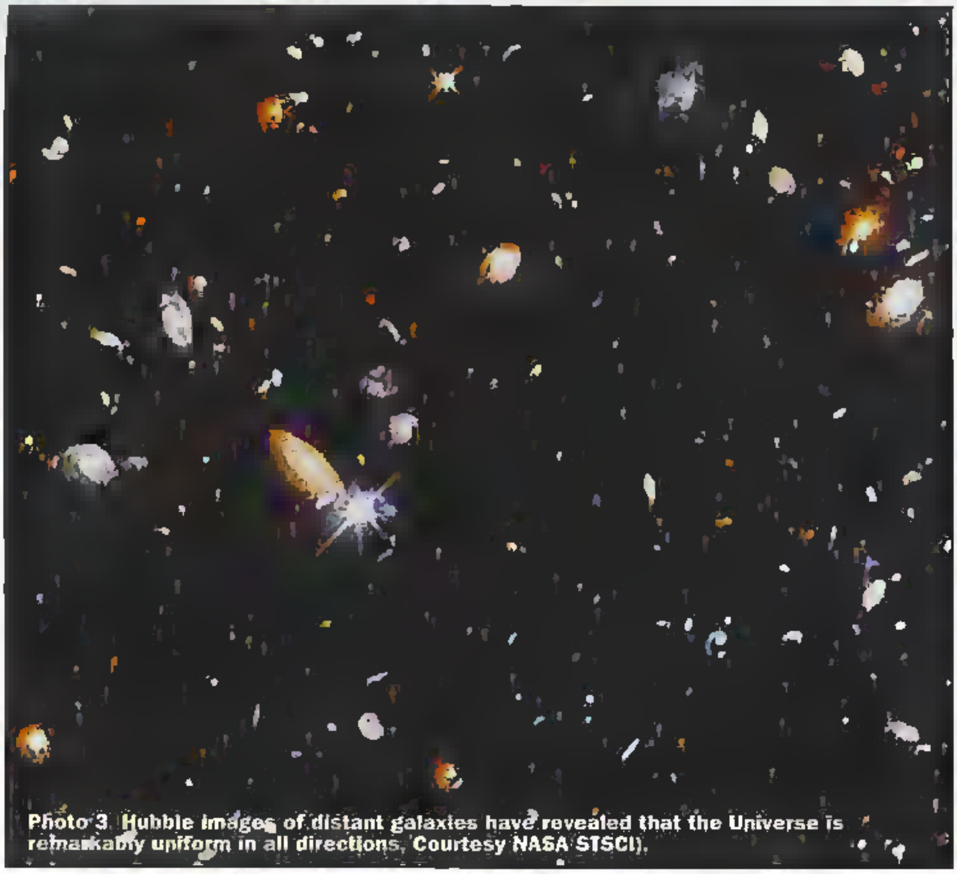


Photo 3. Hubble images of distant galaxies have revealed that the Universe is remarkably uniform in all directions. Courtesy NASA STSCI).

mainstream active presently which is trying to come to grips with the many challenges of thought triggered by the discoveries of science. These are interesting times in the mind of the Cosmologist.

Consciousness Revisted

In the books on popular science, we still see many which refer to the mysteries of human consciousness as a topic linked to 'explaining the universe'. Almost as if someone is tapping chalk on a blackboard, the reminder comes through many of them - our understanding of human consciousness has not advanced to any great significance in the last 100 years despite the best efforts of science. As scientists contemplate a uniform theory of everything, the aspect of human consciousness deftly defies a physical explanation. As various authors, however, put a time limit on unravelling the number of years required to fully 'understand' consciousness in terms of neural networks and Ohm's law, there remain a solid core of others who are skeptical of the ability or even the role of science to find a satisfactory purely physical solution.

The Esoteric Response

Science today thus asks the question - 'Why was the Universe created? Various mainstream religions and philosophies would for their part indicate that the creation of the universe provided an opportunity for consciousness to develop and in so doing for consciousness, by free will, to discover the mind of the Creator. Moreover, some more esoteric sources would indicate that the physical Big Bang was the result of crystallisation of thought, that thought energy was the ultimate source of energy for the Big Bang - a cosmic thought of the Creator. So in looking for the First Cause, as it were, this was initially separate from matter but manifested subsequently as matter.

Cosmic Milestones

The fitting together of some of the many pieces of the jigsaw of creation has taken some time to progress thus far. Most of the significant developments have taken place in the 20th century, through Newton's 'discovery' of gravity has until very recently been thought to be the most critical factor in the long term survival of the physical universe and also the most difficult to explain as part of a unified theory of everything.

While there had been speculation of the nature of the Milky Way as being a vast local collection of stars, it was the completion of the 100 inch telescope at Mount Wilson near Los Angeles that gave Edwin Hubble in the 1920's the opportunity to resolve individual stars within so called Messier Objects such as M31 and M33. It had been known for some time that cycles of stellar evolution gave rise to so called Cepheid variable stars whose variation in brightness with time could be related to their absolute luminosity. This provided a means of determining the relative distance of such stars at the very edge of the then visible universe. By observing the characteristic

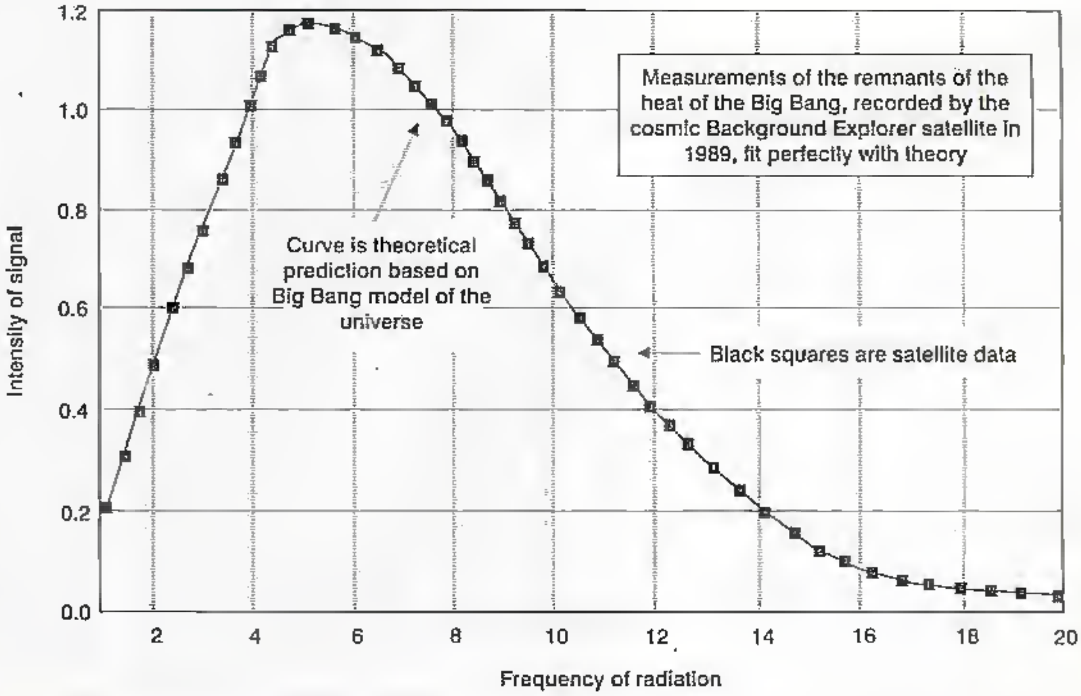


Figure 2. Data obtained by the Cosmic Background Explorer Satellite in 1989. The data points shown as squares provides a perfect fit to the 2.76 K black body radiation.

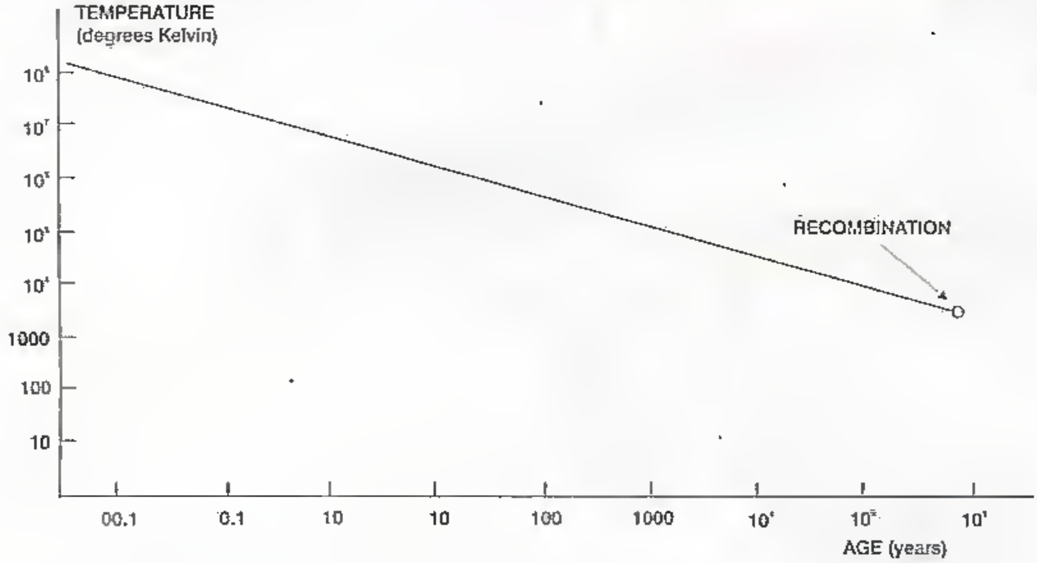


Figure 3. Process of cooling of universe. Each cooling by a factor of 10 is associated with a volume expansion of a factor of 10.

wavelengths (red shift) of lines emitted by such stars it was determined from the Doppler principle that the more remote galaxies were in relative terms moving faster away from us. In fact, the very early data that Hubble collected would appear unconvincing today, though subsequent observations would more than confirm his theory as indicated in Figure 1 which shows levels of red shift as a function of distance to object observed. One of the problems, however, of this approach is the sheer problem of extending the observation distance to more and more distant galaxies and hoping to observe specific Cepheid variable stars. The universe is still expanding with the best current estimate of expansion of the order of 15km per second per million light years - the Hubble constant. The age of the Universe, however, has not been absolutely determined but is probably in the region of between 10 and 20 billion years. This is the level of expansion which is assumed the universe is currently undergoing throughout its entirety. To provide some perspective in the rate of expansion of the universe, if a sphere of radius 1000 million light years is considered, in one year it will expand by a factor of 0.000000005 % or equivalently it would take a billion years to expand by a factor of 5%. The rate of expansion must be slowing down, however, as the relative gravitational energy of galaxies becomes a less negative term - i.e. as they try to free themselves from mutual gravitational attraction. The question as to whether the Universe's expansion will keep on going as an 'open' expansion or attract back on itself under gravity as a 'closed' expansion has not yet been completely determined. Until very recently the key factor was considered to relate to the average density with which mass is distributed in the Universe. Current estimations of mass range from between 6 to 0.03 nuclear particles (neutrons,protons) per thousand litres. Recent work relating to determine any residual mass value of the neutrino is seen as a crucial factor in such determinations. Investigative science has therefore a lot of fundamental discoveries to make before this issue is settled. Also, the recent work in observation of distant supernova on the edge of the visible universe - suggesting that the expansion of the Universe is accelerating - has thrown Cosmology in a spin.

There is also the suspicion that since the interaction between neutinos and matter/antimatter is so small, there could still be significant levels of antimatter in the universe in the form of anti-neutrinos. As time goes on, does this imply that even this mass component of the universe is not in a steady state but is slowly declining with time? Future work in particle physics will in addition be seeking particles of so called Dark Matter in order to account for the large component of apparent missing mass in the universe. To date only around 10% of matter can be accounted for by direct astronomical observation.

An Eagle Eye

The Hubble Space telescope has enabled resolution of the most distant optical images so far captured. In setting the telescope to look to the very furthest limits of resolution, photo 2 shows images of deep field galaxies at the very edge of the present detectable universe. Some of the galaxies are 30th magnitude in brightness. What is revealed is a bewildering array of types of shapes and colours of galaxies in a tiny spec of the sky.

Analysis of many images of distant galactic fields indicates that the Universe is statistically the same in all directions - providing some clues about the uniformity of the process of expansion of the early Universe, Photo 3 indicates a typical field of galaxies indicating a range of types and sizes of galaxies present.

The Cosmic Microwave Background

The physical universe that we know today is regarded as one which evolved from earlier beginnings. It is estimated that at one phase during the initial expansion when protons, neutrons and electrons had become stable, there was intense characteristic radiation in the form of photons at a characteristic Black body radiation of around 3000 K. The Universe then was a very 'bright' place. As the space of the Universe expanded, the individual energy of these photons was correspondingly diminished as their energy became spread over a much larger volume. The remnants of this original 'big flash' radiation is been as a characteristic Black Body radiation at an equivalent temperature of around 3°K. Figure 2 shows the data obtained by the Cosmic Background Explorer Satellite in 1989. The data points shown as squares provides a perfect fit to the 2.76 K black body radiation.

This background radiation was first discovered in 1964 by two radio astronomers, A. Penzias and Robert W Wilson. This analysis also provides information on the energy density of such photons - providing in the process an indication that most of the energy of the universe now is in the form of matter, while during the initial phase of the Universe, most of the energy was in the form of high energy photons.

In fact, the remnants of this early radiation field indicate that in winding back the clock of time as the universe became smaller, it became consequently hotter as characterised by the energy of photons present. In respect of this, photons of pure energy could begin to produce particles of physical matter. Electrons and positrons can be considered to form from photons of energy of characteristic temperature 5.9 x 10^9 K and protons and neutrons at significantly higher energies of 10^{13} K. Figure 3 indicates the principle of cooling of the Universe which has been considered to have undergone since the start of time. Thus for a reduction of temperature by a factor of 10, is associated a time factor of 10. As physical particles were formed, they were formed as matter and antimatter types, with an imbalance of the order of one part in 1000 million in favour of matter particles. The remaining particles of matter remain as evidence of the much greater numbers of particles of both types that would have been formed but which annihilated themselves. Thus the sheer existence of the physical universe is as a result of the infinitesimal lack of symmetry between matter and antimatter. As might be expected, scientists are very keen to determine exactly why this is so. If the symmetry was exactly zero, then no physical universe would exist at all.

Next month we look at how technology yeilds some answers.

Psion 5 In-Car POWER ADAPTOR: A STUDY IN SWITCHING REGULATOR DESIGN

Neil Johnson of Cambridge Consultants Ltd., discusses the design of a compact 12V to 6V switching regulator.

Power supplies based on simple linear regulators are fine for simple applications, where the demands for efficiency, space and thermal design are light. However, as these requirements become more important, the switching regulator offers a more viable solution.

For many designers, these inherently simple devices are shrouded in mystery, deep in the realm of electromagnetic design. This article intends to shine some light on this topic. To help us all understand the theory behind switching regulators we will also look at the design of an in-car power adaptor for a Psion 5 personal organiser, but can be used for any suitable device requiring 6V. All stages of the design will be fully illustrated throughout, so you should be able to apply the same techniques when designing your own switching regulator.

Linear Regulators – Not!

Before even considering the design of a switching power supply let us look at why we cannot get away with using a simpler linear regulator. Most linear regulators, typified by the familiar 78xx series three-terminal regulators, are very nifty devices. They are based around a pass transistor, error amplifier and voltage reference, as shown in Figure 1.

Considering the external simplicity of these regulators there is a lot going on inside. To understand how it works, we will start at the output and work our way back to the input.

The output voltage provides current for resistor R1 to bias diode D1. This generates a temperature-stable reference voltage, V1. Divider network R2 and R3 tap off a portion of the output voltage, providing the feedback signal V2, which is fed into the error amplifier U1.

The life of U1 is very tiresome: it spends all of its time trying to keep V2 equal to V1 by varying the drive to the base of pass transistor Q1. The thermal shutdown module constantly monitors the temperature of the silicon and if it gets too hot it shuts down the device, at least until the temperature drops.

We all know they work. We have all used them as little black boxes for a quick and easy way to get a clean, stable, regulated supply for a project (typically 12V for analogue circuits and 5V for digital circuits). But what is wrong with this rosy picture? Why do some designs need a switching regulator, while others are quite happy with a linear one? Well, there is no one single answer. Instead, there are a number of parameters that combine to make the choice between switching and linear. Here we will look at some of the more important ones.

The Efficiency Drive

Switching regulators are generally more power efficient than linear regulators. In the linear regulator the pass transistor is always passing current, being neither fully saturated nor turned off. In the steady state, the pass transistor acts as a resistive element, carrying the load current and the difference between the supply voltage and the output voltage. The power dissipated by the pass transistor is the product of these two quantities:

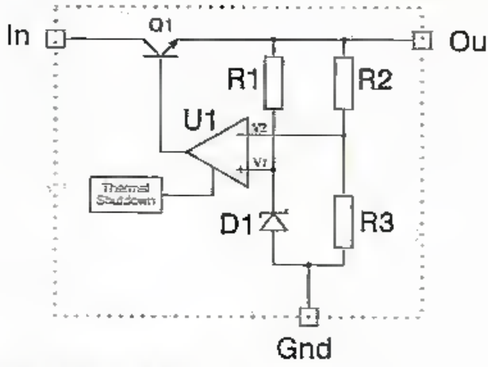


Figure 1. Three terminal regulator: unsung hero of the electronics age.

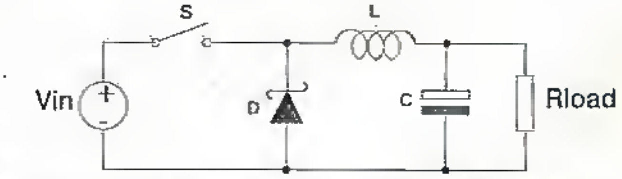


Figure 2. The four basic components of a buck converter.

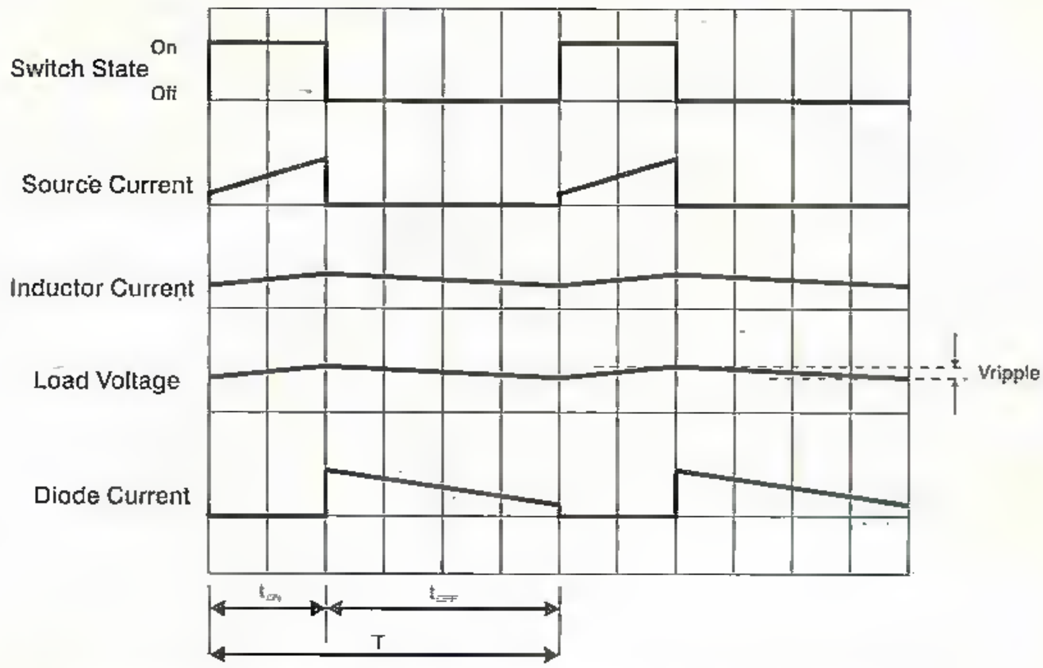


Figure 3. The Buck converter switching cycle. Vripple is due to non-ideal components.

$$P_d = I \times V_{io} \text{ (Watts)}$$

Where P_d = *power dissipated by the pass transistor*
I = *load current*
V_{io} = *difference between input and output voltages*

For example, suppose the input voltage is 15V, the output voltage is 5V, and the current drawn by the load is 1A. Then the pass transistor must dissipate 10W of power. This power manifests itself as heat – the whole regulator will get hot. To maintain the regulator at a safe operating temperature (else the thermal cutout will turn off the regulator) a large heatsink will be needed.

The efficiency of this regulator is the ratio of the output power to the input power

$$n = P_{out} / P_{in} \text{ (\%)}$$

Assuming the input current is equal to the output current, this can be rewritten as

$$n = V_{out} / V_{in} \text{ (\%)}$$

For our example above, the regulator is operating at about 33% efficiency. To put it another way, over 66% of the power provided by the source is being wasted.

Now, what does this seemingly inexcusable lack of efficiency really mean? We need a big transformer to provide more power than is actually needed. We also need a large heatsink to help the regulator dissipate all that waste energy. We have to consider carefully where to mount the regulator – all that waste heat has to go somewhere. The heat radiated by the regulator and its heatsink will heat up surrounding components, slowly cooking them to a premature death.

However, it is not all doom-and-gloom for the humble linear regulator. It is very cheap, costing a few pence for the smaller devices. The surrounding circuit is about as simple as possible – two capacitors. And, of particular importance to analogue signal processing systems, there is little noise present in the regulated output.

Enter The Switcher

For most purposes the advantages of linear regulators outweigh their disadvantages, which is why they are so prevalent, universal and cheap. But most does not equal all. There are situations where lack of efficiency and/or excess heat is a very real problem, and these are the situations where switching regulators have taken over.

The emergence of the desktop computer has been a major force in pushing power supply technology to produce ever cheaper and more efficient power supplies. The higher efficiency means smaller heatsinks and more compact designs. And removing the need for large bulky transformers drastically reduces the overall cost of the unit.

The power supply design described here provides a regulated 6V output, and able to deliver up to 1A, from a 12V source. If a linear regulator were used we would need a heatsink to dissipate up to 6W of waste power. Using a switching regulator, whose efficiency is about 80%, we only waste about 1W of power, and we do not need a heatsink.

Super Features

So far we have only compared like with like features of the linear and switching regulators. But this is only half of the picture. Switching regulators can do things that linear regulators cannot – output voltages greater than the input, and output voltages of opposite polarity to the input. Both these features put switching regulators way ahead of linear regulators.

There are many basic switching regulator designs, or topologies, but the two most common are the buck and the boost. There are many others, for example the flyback regulator, and also hybrid combinations of different topologies, for example the buck-boost.

The buck converter produces an output voltage that is less than the input voltage. At a 'black box' level it behaves exactly the same as a linear regulator. However, it can operate at a much higher efficiency, typically 80-90%. The basic layout of a buck converter is shown in Figure 2.

The operation of this regulator has two distinct phases. The first one occurs when the series switch, S, is 'on' and the input voltage is connected to the input of the inductor. The output of the inductor is the output voltage, and the catch diode, D, is reverse biased. During this period, since there is a constant voltage source connected across the inductor, the inductor current begins to linearly ramp upwards as described by the following equation:

$$I_{on} = (V_{in} - V_{out}).T_{on} / L$$

Where I_{on} *is the inductor current during the on phase*
V_{in} *is the input voltage*
V_{out} *is the output voltage*
T_{on} *is the on time*
L *is the value of inductance*

During this 'on' period, energy is stored within the core material in the form of magnetic flux. If the inductor is properly designed, there is sufficient energy stored to carry the requirements of the load during the 'off' period.

The next period is the 'off' period. When S turns off, the voltage across the inductor reverses its polarity and is clamped at one diode voltage drop below ground by catch diode D. Current now flows through D thus maintaining the load current loop. This removes the stored energy from the inductor. The inductor current during this time is:

$$I_{off} = (V_{out} - V_d).T_{off} / L$$

Where Ioff is the inductor current during the off phase
V_d *is the voltage across the catch diode D*
T_{off} *is the off time*

This period ends when S is once again turned on. Regulation of the converter is accomplished by varying the duty cycle of the power switch. The duty cycle is determined by the ratio of T_{on} to the overall switching cycle T:

$$D = T_{on} / T$$

Where T is the period of switching
Ton is the duration of the 'on' period

For the buck converter with ideal components, the duty cycle is defined by the ratio of the input and output voltages:

$$D = V_{out} / V_{in}$$

The complete cycle is illustrated in the waveforms of Figure 3. With ideal components there would be no ripple on the output. However, the non-ideal resistance in the inductor gives rise to some ripple in the output (Vripple).

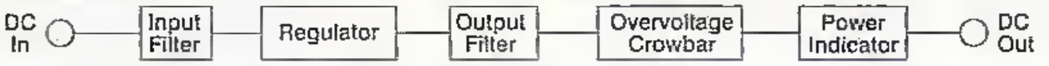


Figure 4. Block diagram of the Psion 5 In-Car Power Adapter.

Putting Theory Into Practice

We have now seen the arguments for using switching regulators, and covered the basic theory of operation for the buck converter. The remainder of this article will look at the design of a power supply to provide 6V at up to 1A from an unregulated supply in the range 11 to 15V. The PSU is intended to power a Psion 5 personal organiser computer from a car cigarette lighter socket. It could be used for any number of other applications by changing some of the components.

The top-level block diagram of the power adapter is shown in Figure 4. The primary purpose of the input filter is to block any switching noise from the regulator from finding its way out into the car's power lines. If left unattenuated this noise could be picked up by the car's radio, causing unwanted interference.

The regulator converts the input power to a regulated 6V, which is then filtered by the output filter, this time to provide a clean output signal, but also to, again, limit the spread of switching noise.

The overvoltage crowbar and associated fuse is provided as an emergency protection for the load. One failure mode of any switching device is to short the input to the output, which could be disastrous for the load. The crowbar circuit senses the output voltage and, if it exceeds a set threshold, will automatically put a short across the supply, blowing the fuse and protecting the load.

Finally, some indication of the supply status is provided, primarily for the user's benefit.

Square One

Turning the block diagram of Figure 4 into a circuit is the next stage in this design study. During the design process there are many options available for customising the circuit. They will be highlighted at the relevant points.

1 – The Regulator

The first block to consider is the heart of the adapter – the regulator. The device chosen for this project is the LM2585T-ADJ, available from a number of manufacturers (National Semiconductor and Motorola to name but two). The 'ADJ' signifies this is the adjustable output version of the LM2575 family. The other members of the family provide fixed outputs of 3.3V, 5V, 12V and 15V. The 'T' means the device is in a 5-legged TO-220 package.

The LM2575 regulator packs a lot of functionality into a very small package. It can supply up to 1A, has an internal oscillator running at 52kHz, has a shutdown mode for low power operation, is very efficient (typically 80%), has a built-in 1.23V reference, and has thermal shutdown and current limit protection.

The regulator needs a few additional components to build a switching regulator system. We saw earlier that as well as a switch, we need a diode, an inductor and a capacitor.

Since the circuit will be running at 52kHz we need a diode with a fast recovery time. Ordinary silicon rectifier diodes, like the 1N4001 family, are much too slow for this purpose. Instead, a fast switching Schottky diode is needed. For this project a 1N5819 is suitable.

The choice of inductor is crucial to the success of this design. It must be large enough to be able to store enough energy to power the load during the 'off' phase. It must have a low loss to ensure a high efficiency. And it must have a low DC resistance to keep the output ripple as low as possible and to reduce the loss of energy due to current heating in the wire (so-called 'I-squared-R' losses). The mathematics involved in deciding on a value for the inductor is shown in Figure 5.

The value calculated from Figure 5 is 330μH. Looking through the latest Maplin catalogue (you did not think I was going to look anywhere else, did you?) there is a suitable inductor, code BU57M, with the added advantage of it being wound on a toroidal core. Toroidal cores are very good at keeping the magnetic flux within the confines of the core, for low loss, which has the added benefit of reducing stray magnetic fields inducing noise in other, nearby, circuits.

The output capacitor must be chosen to satisfy two conflicting requirements – capacitance and effective series resistance (ESR). In general, as capacitance increases, so does ESR, mainly due to the physical construction of the capacitor. Needless to say, what is required is a big capacitor with a low ESR.

For this application a capacitor with an ESR of 0.1Ω, or less, and a minimum capacitance value of 330μF is required. The nearest available component from the Maplin catalogue is a 470μF 35V low ESR radial electrolytic. And it comes in a bright pink can.

So far, the components chosen for the regulator will be suitable for most applications of the LM2575 series. For some applications, where the average current drawn by the load is close to 1A the diode should be uprated to one capable of handling

From

$$I_{L(on)} = \frac{(V_{in} - V_{out})t_{on}}{L}$$

and

$$t_{on} = \frac{V_{out}}{V_{in}} \frac{1}{f_{osc}}$$

we can derive

$$I_{L(on)} = \frac{(V_{in} - V_{out})}{L} \frac{V_{out}}{V_{in}} \frac{1}{f_{osc}}$$

Assume $I_{L(avg)} = I_{L(on)}$ and rearrange to solve for L:

$$L = \frac{(V_{in} - V_{out})}{I_{L(avg)}} \frac{V_{out}}{V_{in}} \frac{1}{f_{osc}} \text{ H}$$

Now putting in design values for V_{in}, V_{out}, $I_{L(avg)}$ and f_{osc}

$$L = \frac{15.0 - 6.0}{1.0} \frac{15.0}{6.0} \frac{1}{52\text{kHz}} \text{ H}$$

$$L = 69.2\ \mu\text{H}$$

The value calculated from the above equations assumes ideal components. To allow for the inadequacies of real components a factor of 5 should be applied to the above value. The nearest preferred value would then be 330μH.

The value of output capacitor must satisfy the following condition:

$$C_{out} \geq 7{,}785 \frac{V_{in_{max}}}{V_{out}L} \text{ F}$$

Putting in component values, we get:

$$C_{out} \geq 7{,}785 \frac{15.0}{6.0 \times 330\mu\text{H}}$$

$$C_{out} \geq 59\mu\text{F}$$

However, for acceptable output ripple voltage use a much higher value, for example 470μF.

Figure 5. The values of the main inductor and capacitor can be calculated with the aid of some basic algebra and rules of thumb.

From $V_{out} = V_{ref}\left(1 + \frac{R_2}{R_1}\right)$

where $V_{ref} = 1.23$V

By setting R1 to 1.0k, 1%

V_{out} to 6.0V, and rearranging:

$$\frac{V_{out}}{V_{ref}} = 1 + \frac{R_2}{R_1}$$

$$R_2 = R_1\left(\frac{V_{out}}{V_{ref}} - 1\right)$$

$$= 1000\left(\frac{6.0}{1.23} - 1\right)$$

$$= 3878\ \Omega$$

The nearest preferred value for R2 is 3k9, which should be a 1% tolerance component.

Figure 6. With the value of R1 fixed at 1k, the value of R2 is set the by the desired output voltage.

From $f_c = \frac{1}{2\pi\sqrt{LC}}$ Hz

rearranging we get:

$$(2\pi f_c)^2 = \frac{1}{LC}$$

$$L = \frac{1}{C(2\pi f_c)^2}$$

An LC lowpass filter has a cut-off rate of 6dB. For a reasonable degree of attenuation of the switching frequency, say 24dB, we need a cut-off frequency, fc, of 3250Hz. Inserting the values of C and fc, the value of L calculated from above is 24μH. The nearest preferred value is 22μH.

Figure 7. The filter inductor, together with the capacitor, forms an efficient lowpass filter.

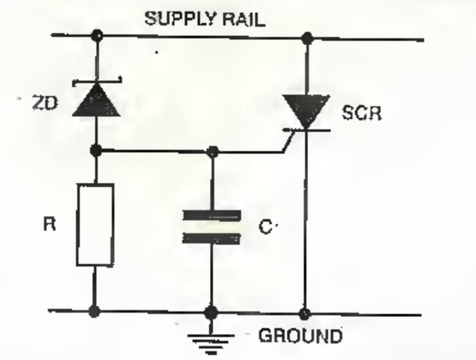


Figure 8. A simple and effective crowbar.

more than 1.5A (for example a 1N5822, order code AL08J).

The last part of the regulator to consider is the feedback network. The network is actually a potential divider, setting the feedback pin to some fraction of the desired output voltage. The worked example in Figure 6 shows how the values of the two resistors are calculated. With a bottom resistor of 1k0, the top resistor value must be 3k9. Both resistors should be 1% tolerance or better.

Using the equations of Figure 6 it is possible to calculate values of resistance for any desired output voltage. If one of the fixed output regulators is used, the bottom resistor should be omitted, and the top resistor replaced with a wire link.

2 – The Filters

The next two blocks are the input and output filters. Since they must filter out noise of the same frequency they can be made from the same valued components. Because the load current passes through the filters they should be as energy efficient as possible. This precludes the use of any resistive elements, so we have to use an entirely reactive filter made from inductors and capacitors. For this application a single LC filter will be sufficient.

The data sheet for the regulator recommends a low ESR capacitor of 100µF be placed close to the input pin. This neatly answers the question of what value capacitor to use. The value of the inductor is calculated from some maths and some rule of thumb, shown in Figure 7. For an attenuation of approximately 30dB of the switching noise, and given that an LC filter has a cut-off rate of 20dB per decade, the filter needs to have its –3dB point at about 4kHz.

A diode should be connected in series with the input filter to protect the filter and regulator from accidental reverse connection. The cost of the regulator – seven pounds – more than justifies the additional cost of a five pence diode.

3 – Load Protection: Fuse and Overvoltage Crowbar

The next major circuit block to consider is the overvoltage crowbar circuit. The purpose of this section is quite simple: monitor the output voltage and throw a short across the output if the voltage exceeds a pre-set threshold.

The crowbar itself is a thyristor connected directly across the output. When the sensing circuit turns on the thyristor, it shorts the power supply by placing a 1V dummy load across the rails. It passes all the current the supply can provide before the fuse blows, cutting off any further current. During this brief on state the output voltage is reduced to about 1V.

Scanning through the Maplin catalogue a likely candidate is the CP106D. It comes in a small TO-92 package, has a continuous current handling capacity of 2A, and can handle peak currents of 15A. This gives plenty of headroom to allow the fuse to blow before the thyristor itself dies.

The sensing part of the crowbar uses a zener diode and load resistor. The zener diode monitors the output voltage. When it exceeds the zener voltage (plus a diode drop for the thyristor) the diode will conduct current into the load resistor and into the thyristor's gate, turning it on.

The circuit for the crowbar is shown in Figure 8. The thyristor is shown labelled as an SCR (Silicon Controlled Rectifier), which is just another name for a thyristor. The name 'thyristor' is itself a contraction of 'THYRatron transISTOR', a thyratron being a gas-filled thermionic valve that exhibits a similar switching characteristic.

The value of R sets the zener on current. This should be about 10mA, which gives a value of R of about 68R. The capacitor C is there to absorb any harmless spikes on the voltage rail that might accidentally trigger the crowbar. The knee voltage of the zener diode should be about one diode drop less than the desired threshold voltage. For this circuit a 6.2V zener diode would be sufficient.

4 – Power Indication

The final part of the circuit to design is the power indicator. No prizes for guessing that an LED and current limiting resistor are going to be used. Assuming an LED voltage of 1.7V, and a current of 10mA, we need a current limiting resistor of 430R.

Putting It All Together

Now that all the various parts of the system have been designed we can connect them all together, resulting in the circuit of Figure 9. By now you should recognise most, if not all, of the components in the circuit.

The input power enters the circuit through protection diode D1 and input filter L1, C1. This feeds directly into the regulator, IC1. The switching output feeds the other buck converter components D2, L2 and C2. R1 and R2 feed a fraction of the output voltage back to the converter. Pin 5 of the regulator is the shutdown pin, and is pulled low to select continuous operation.

The output filter, L3 and C3, passes the output to the protection fuse FS1, before passing over the ever-vigilant crowbar, consisting of D4, R4, C4 and D5. Finally, R3 and D3 provide power indication.

Because switching regulators suffer from high switching current circulating around the circuit some care must be taken when laying out the printed circuit board (PCB). The tracks that need extra thickness and short lengths are highlighted in Figure 9 by the thicker lines.

The PCB foil pattern for this project is shown in Figure 10. Referring back to Figure 9 you can see that the critical circuits are laid out with thicker tracks. Radiused corners have been used where necessary, generally trying to keep all tracks as direct and as short as possible.

Construction

The component overlay for the PCB is shown in Figure 11. All components mount directly on the single-sided board, and there are no wire links, so building the power supply should be quite straightforward.

Start with the smaller components – the diodes, resistors, PCB pins (if used), fuse clips, LED and capacitor C4. Then work your way up through the larger components – L1, L3 and the remaining capacitors – before fitting the main inductor, L2. Remember to take particular care with the polarised components, especially the electrolytic capacitors.

The final component to fit is the regulator itself, IC1. This is mounted directly on the PCB, and does not need a heatsink. Make extra sure the device is properly oriented, with the metal back of the device facing away from L2.

Give the board a thorough clean with a stiff brush and some iso-propyl alcohol (IPA) or other flux-removing agent. Once

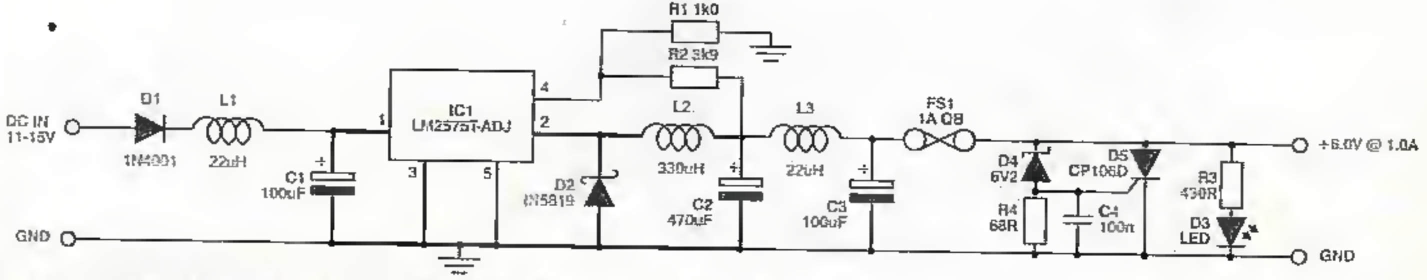


Figure 9. Putting it all together. Note the critical paths marked with extra thick lines.

all of the flux residue has been cleaned off give the board a close inspection with a magnifying glass to check for solder splashes and to check the quality of all the joints. Clean up or repair any suspicious joints.

Testing

Before using the power supply in its intended application it should be tested to make sure that a) it actually works, and b) will not damage whatever it is connected to. This second point is especially relevant given the potentially high voltages that could be presented to the load.

Testing this project will require some key items of equipment. Firstly, a decent multimeter, preferably with a DC current range of 1A or greater. This will be used to measure the output voltage and the current drawn from the supply.

Secondly, some sort of dummy load is required to test the regulator at a number of load currents. Three spot values of load current should be sufficient. For example, 100mA, 500mA and 1A, requiring load resistors of 60R at 0.6W, 12R at 3W, and 6R at 6W respectively.

Thirdly, a bench power supply capable of delivering 15V at up to 1A. The unit should also have some sort of adjustable current limiting device, just in case something goes terribly wrong.

Finally, for the more curious, an oscilloscope for observing and measuring the various waveforms present within the switching regulator.

Begin by connecting the PCB to the bench power supply, putting an ammeter in the positive supply rail. Set the current limit to about 500mA, the ammeter range to 1A, and turn on.

The needle of the ammeter should flick over to the right hand side of the scale before settling back towards zero. This is the turn-on surge that most simple switch-mode power supplies exhibit, and is primarily due to the main capacitor charging up.

After a couple of seconds the current should have settled down to a steady value of a few milliamps. The only load of the regulator at the moment is the 10mA or so drawn by the LED. The current drawn from the supply should be a little over a third of this, allowing for the efficiency of the regulator.

Using a voltmeter check the output of the regulator is very close to 6.0V. Also carefully check all of the components on the board to see if any are getting hot. At this stage of operation everything should be cool to the touch. If not, switch off immediately and investigate the cause.

The next three stages in testing involve our dummy loads. Disconnect the regulator from the supply and connect the 60R dummy load. Reconnect the regulator to the supply and check the input current is about 50mA and the output voltage is 6V, give or take a small margin of error of 0.5V.

Repeat the same test for the other two dummy loads. For a load current of 500mA the supply current should be about 260mA. For the 1A dummy load the current limit on the supply should be raised to 1A. In the steady state, the current drawn from the supply should be about 500mA.

Testing the over-voltage crowbar is a bit trickier. Remove the protection fuse FS1 and connect a lead from the positive output of the supply to the output side of the fuse holder (the clip furthest from L2). Set the current limit of the supply to about 50mA. Slowly increase the supply voltage until the crowbar activates and the supply current limiter kicks in. This voltage should be about 6.8V.

If all is well, disconnect the supply and replace the fuse. You are now the proud owner of a switch-mode power supply!

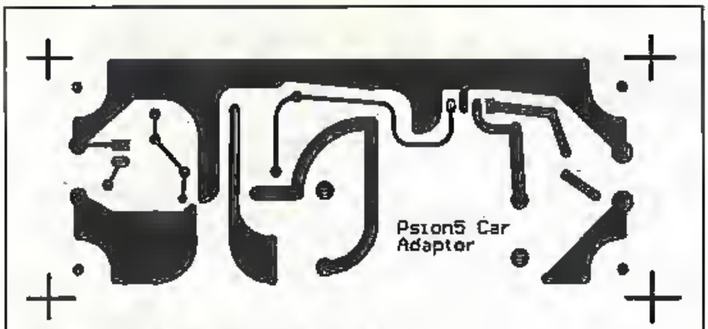


Figure 10. Foil pattern for the PCB.

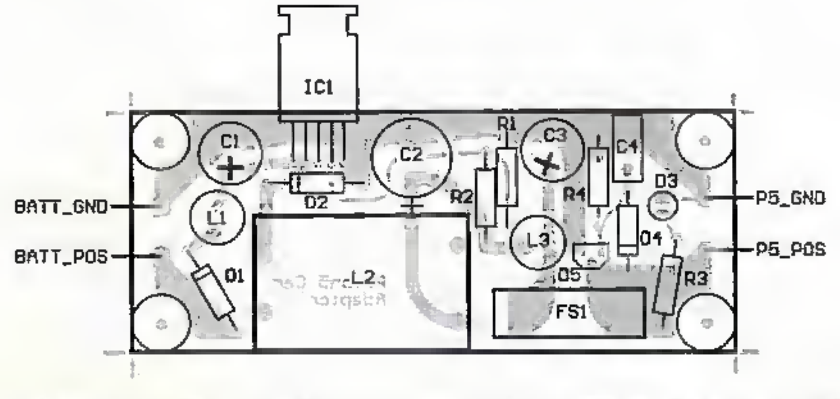


Figure 11. Component overlay. The circles at the corners are to allow clearance for M3 washers.

Usemore, not useless!

The project described here has taken us from initial design techniques through to a working switching regulator module. The most obvious and immediate application for it is as an in-car power converter for a Psion 5 personal digital assistant. To complete the project, you will need a car lighter socket connector, a DC connector for the output, and a case to house it in. And there you have it. End of project. Or is it? Well, not quite.

A small, simple, and efficient switching regulator has a wide range of uses. These can range from operating other in-car equipment, to providing a local supply inside a larger piece of equipment. There are literally hundreds of uses for this module, all possible with one or two minor changes.

The description of the design of this module briefly looked at ways of modifying the circuit for other uses. In particular, varying the output voltage can be achieved in two ways.

The first way is to change the upper resistor, R2, in the feedback network. Figure 6 illustrates the steps necessary to calculate the new value given the desired output voltage. A variation on this approach is to make R2 a variable resistor. This would realise an adjustable 1A power supply with all the benefits of this design (high efficiency, low output ripple, and small size).

For example, a 22k potentiometer in place of R2 would give an output voltage range of between 1.2V and 28V. The power source for this regulator should be able to provide about 35V at up to 1A. A transformer, rectifier and large reservoir capacitor would be sufficient, as the switching regulator and output filter are responsible for providing a clean, regulated output.

The second way of changing the output voltage is to replace the variable output regulator with a fixed output regulator. There are a number of regulators available, with outputs of 3.3V, 5V, 12V and 15V. They should be used in place of the adjustable regulator for these specific voltages. The important difference is that they do not need an external feedback network, as it is already built into the regulator. On the PCB resistor R1 should be removed and resistor R2 replaced by a wire link.

These two simple modifications turn this project into a jack of all trades, with hundreds of possible applications - enough to fill an entire book. But this is a magazine, so we will only look at a few uses, and leave the rest up to your creative minds.

1 - Portable Power Pack

The high efficiency of a switching regulator makes it ideal for battery-powered applications. Coupled with a rechargeable battery it makes a versatile portable power pack for operating a wide range of appliances.

One possible use is in a bicycle lighting system. One large rechargeable battery can provide all the power needed to run a number of LED-based front and rear indicators, power for a tungsten-halogen front lamp, and even a horn. Instead of using a lossy voltage-dropping resistor for each LED, drive them directly from an efficient switching supply. Figure 12 shows the sort of scheme that could be used.

2 - Bench Power Supplies

Combining a potentiometer and an adjustable regulator is an easy way to build a variable bench power supply. The high efficiency of the regulator means you only need a small heatsink, as the regulator body has to dissipate far less waste energy than an equivalent linear regulator. Figure 13 has the details.

The regulator itself has built-in thermal shutdown and over-current protection. For this application the over-voltage crowbar circuit is not needed and can be left off the circuit board. The fuse could remain in circuit, protecting the regulator from excessive load currents.

Another way of building a bench supply is to have a number of fixed outputs. These could provide a set of standard voltages, for example 5V, 12V and 15V. The high efficiency of the regulators means all the regulators can be run from one supply rail with no penalty in waste energy.

3 - Distributed Power System

The final idea is for builders of larger systems. In a system of many boards or modules, requiring a number of different supply voltages, an efficient way of distributing power is to use a high-voltage common supply rail. Each module would then have its own local regulator to derive the required supply voltage.

Switching regulators offer an energy-efficient solution to this design challenge. The global supply could be run at anything up to 60V, cutting down on resistive heating losses and simplifying the internal wiring.

Adding a new module would simply mean adding another local regulator, not a major wiring exercise back to the central power supply.

The Final Act

And so we come to the end of this project. Having thrown back the shrouds of mystery surrounding the switching regulator, we have looked closely at how it works and how we can use it.

As an illustration of the issues covered, a complete power supply design, from initial specification through to final PCB artwork, has been presented. Finally, some ideas for further uses of this versatile module have also been described.

Unfortunately this article cannot hope to cover all of the theory, design techniques and applications of switching regulators. However, there are a growing number of good books on this fascinating subject.

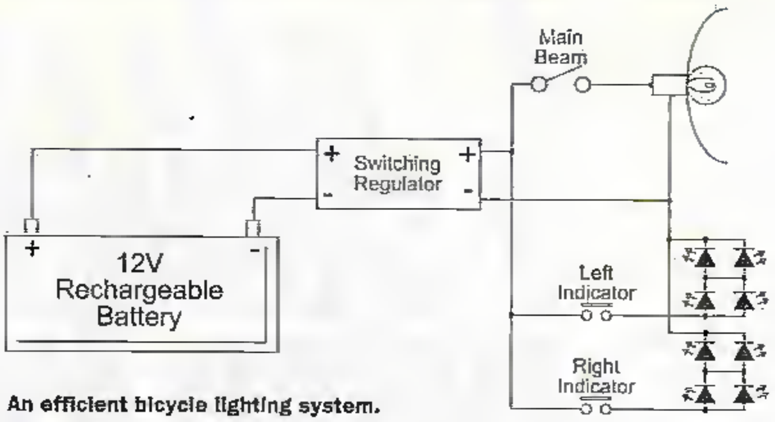


Figure 12. An efficient bicycle lighting system.

A good place to start is the section on switching regulators in *The Art of Electronics* (order code WS20W). Section 6.19 in the second edition starts off with a general introduction to switching regulators, looks at a number of topologies and design studies, before finishing with a collection of useful tips and advice on the selection and use of switching regulators.

For a more in-depth coverage of this topic Keith Billings' *Switch Mode Power Supply Handbook* is an excellent choice. It covers everything needed to design all sorts of switching regulators.

For those who prefer circuits to theory, the *Power Supply Cookbook* by Marty Brown at Motorola is probably more suitable. It also has the advantage of covering linear regulators and also resonant switching regulators for the more curious reader.

As with any book topic it is worth browsing a few books on the subject to find one you can readily absorb.

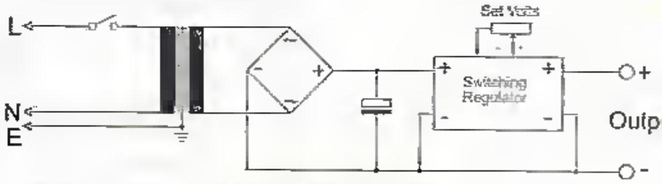
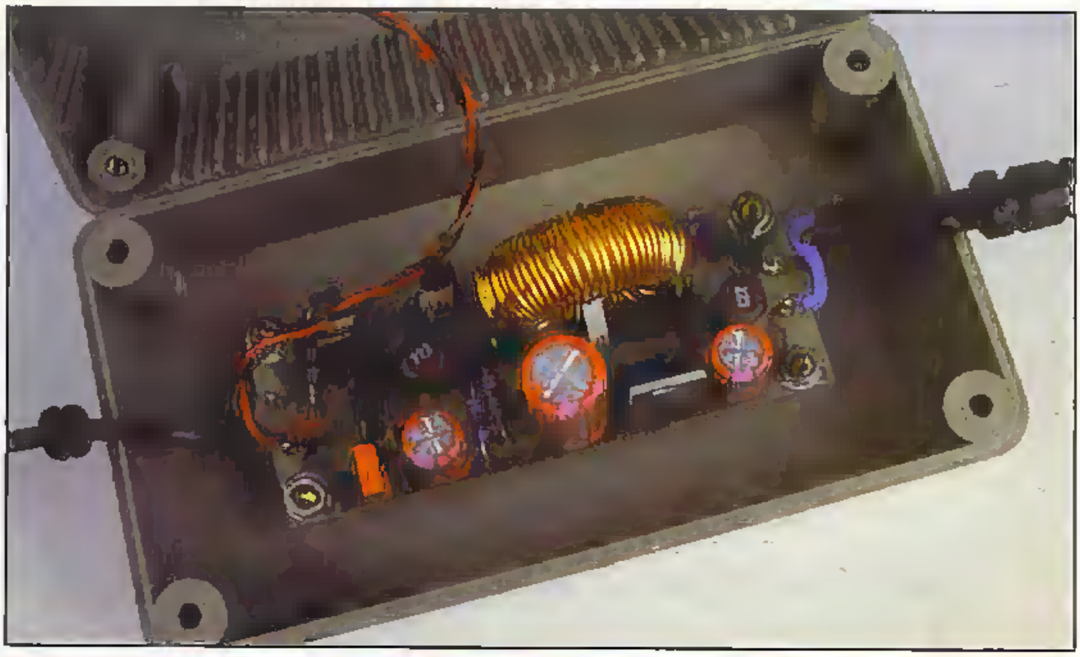


Figure 13. Variable bench power supply.

Acknowledgements

The author would like to thank Cambridge Consultants Ltd, Cambridge, for their assistance with this project. In particular, the author would like to thank Julian Coles for thoughts on switching regulators and their pathologies. And hugs to Helen.



PROJECT PARTS LIST

RESISTORS, all 5% 0.25W unless stated		
R1	1k0, 1%	M1K
R2	3k9, 1%	M3K9
R3	390R	M390R
R4	68R	M68R
CAPACITORS		
C1, 3	100μF 35V low ESR radial electrolytic	VN77J
C2	470μF 35V low ESR radial electrolytic	VN85G
C4	100n polyester	CX21X
INDUCTORS		
L1, 3	22μH, 1A choke	AH28F
L2	330μH 1A switched-mode choke	BU57M
SEMICONDUCTORS		
IC1	LM2575T-ADJ switching regulator	AD86T
D1	1N4001	QL73Q
D2	1N5819	AN07H
D3	3mm red LED	WL32K
D4	BZY88C5V1 5.1V 500mW Zener	QH07H
D5	CP106D thyristor	UM74R
MISCELLANEOUS		
PL1	Car accessory plug	HW12N
PL2	1.3mm DC power jack	FK05F
FS1	1A 20mm Quick Blow fuse	CZ77J
	fuse clips (2 off)	KU27E

PCB, terminal pins, case, wire, solder, mounting hardware (suggest using M3 bolts, nuts and spacers)

Using 7-SEGMENT DISPLAYS

PART 2

Ray Marston looks at practical 7-segment decoder/driver ICs in this concluding part of this special feature article.

Last month's opening episode of this special feature explained the basic operating and usage principles of 7-segment alphanumeric displays. This month's concluding episode of the article deals with practical 7-segment decoder/driver ICs.

Practical Decoder/Driver ICs

Decoder/driver ICs are available in both TTL and CMOS forms. Some of these devices have integral ripple blanking facilities, others have built-in data latches, and a few even have built-in decade counter stages, etc. The rest of this article describes a few of the most popular of these devices.

The 74LS47 and 74LS48

These 7-segment decoder/driver ICs are members of the LS TTL family. They have integral ripple-blanking facilities, but do not incorporate data latches. Figure 1 shows the functional diagrams and pin designations of these devices, each of which is housed in a 16-pin DIL package.

The 74LS47 has active-low outputs designed for driving a common-anode LED display via external current-limiting resistors (Rx), as shown in Figure 2. The 74LS48 has active-high outputs designed for driving a common-cathode LED display in a manner similar to that of Figure 2, but with the display's common terminal taken to ground. The Rx resistors must limit the segment currents to less than 24mA in the 74LS47, and less than 6mA in the 74LS48. The 74LS48 can be used to drive a 7-segment LCD display by using the connections already shown in last month's Figure 11.

Note from Figure 1 that each of these ICs has three input 'control' terminals, these being designated LT (Lamp Test), BI/RBO, and RBI. The LT terminal drives all display outputs on when the terminal is driven to logic 0 with the RBO terminal open or at logic 1. When the BI/RBO terminal is pulled low all outputs are blanked; this pin also functions as a ripple-blanking output terminal. Figure 3 shows how to connect the ripple-blanking terminals to give leading zero suppression on the first three digits of a 4-digit display.

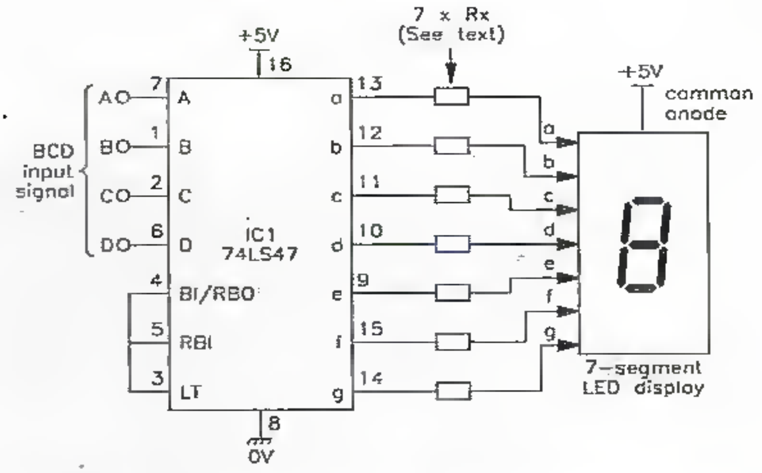


Figure 2. Basic way of using a 74LS47 IC to drive a common-anode LED display.

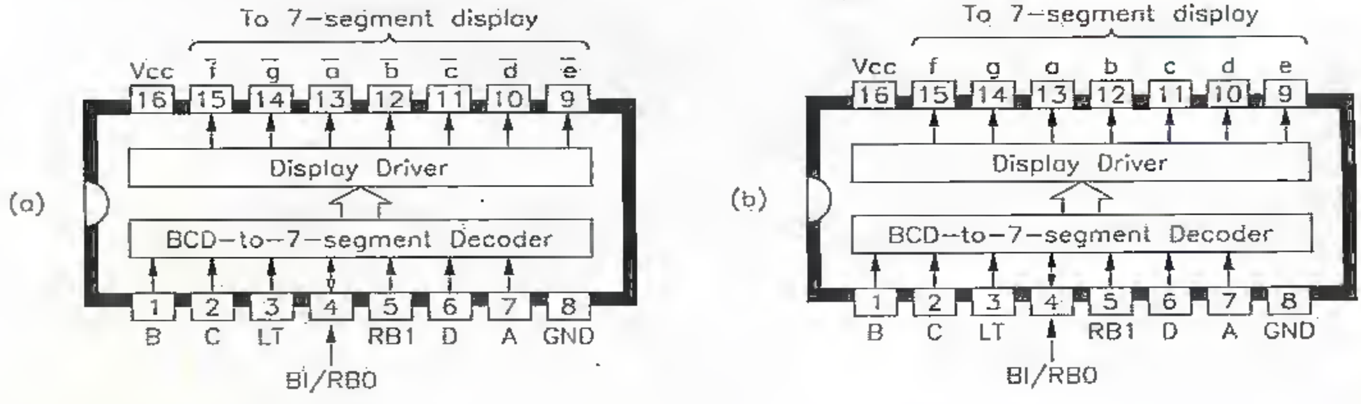


Figure 1. Functional diagram of the (a) 74LS47 and (b) 74LS48 BCD-to-7-segment decoder/driver ICs.

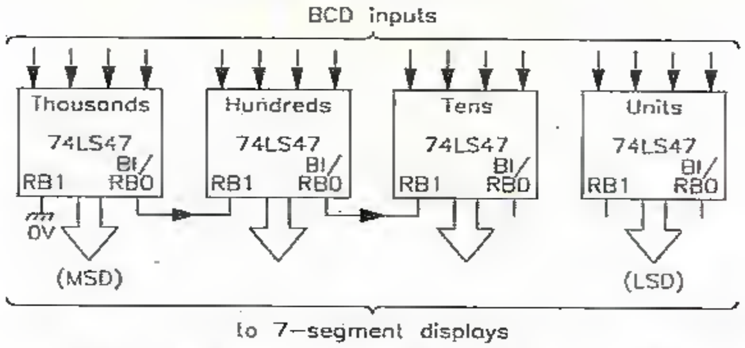


Figure 3. Method of applying leading-zero suppression to the first three digits of a 4-digit display using 74LS47 ICs.

The 4511B

The most popular CMOS 4000B-series BCD-to-7-segment LED-driving IC is the 4511B (also available as the 74HC4511), which has an integral 4-bit data latch but has no built-in ripple-blanking facilities. Figure 4 shows the functional diagram and pin notations of the device, which can use any power source in the 5V to 15V range. The IC is ideally suited to driving common cathode LED displays, and uses npn bipolar output transistor stages that can each source up to 25mA.

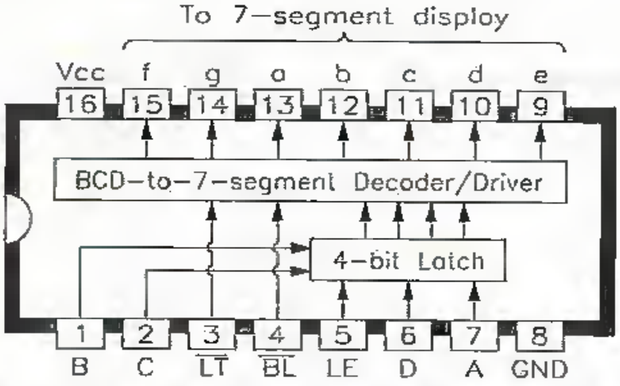


Figure 4. Functional diagram and pin notations of the 4511B 7-segment latch/decoder/LED-driver IC.

The 4511B is very easy to use, and has only three input control terminals; of these, the not-LT (pin-3) pin is normally tied high, but turns on all seven segment of the display when pulled low. The not-BL (pin-4) terminal is also normally tied high, but blanks (turn off) all seven segments when pulled low. Finally, the LE (latch enable) terminal (pin-5) enables the IC to give either direct or latched decoding operation; when LE is low, the IC gives direct decoding operation, but when LE is taken high it freezes the display.

The 4511B can be used to drive most popular types of 7-segment display. Figure 5 shows the basic connections for driving a common-cathode LED display; a current-limiting resistor (Rx) must be wired in series with each display segment and must have its value chosen to limit the segment current below 25mA.

Figures 6, 7 and 8 show how to modify the above circuit to drive LED common-anode displays, gas discharge displays, and low-brightness fluorescent displays respectively. Note in the cases of Figures 6 and 7 that an npn buffer transistor must be interposed between each output drive segment and the input segment of the display; in each case, Rx determines the operating segment current of the display, and Ry determines the base current of the transistor.

The 4511B can also be used to drive 7-segment liquid-crystal displays by using an external

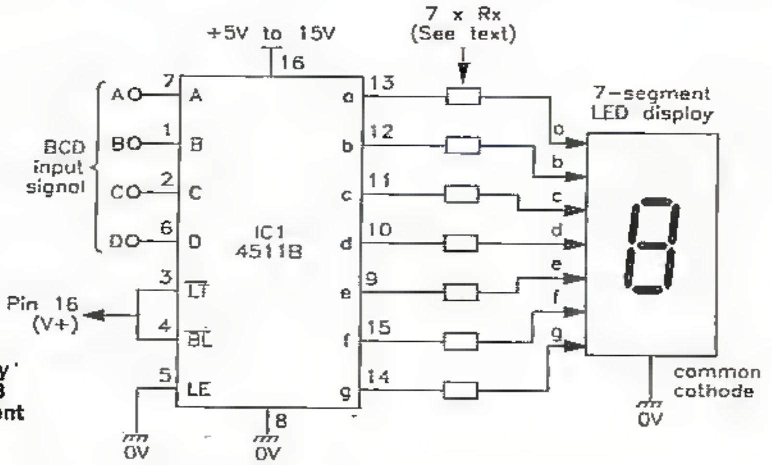


Figure 5. Basic way of using the 4511B to drive a 7-segment common-cathode LED display.

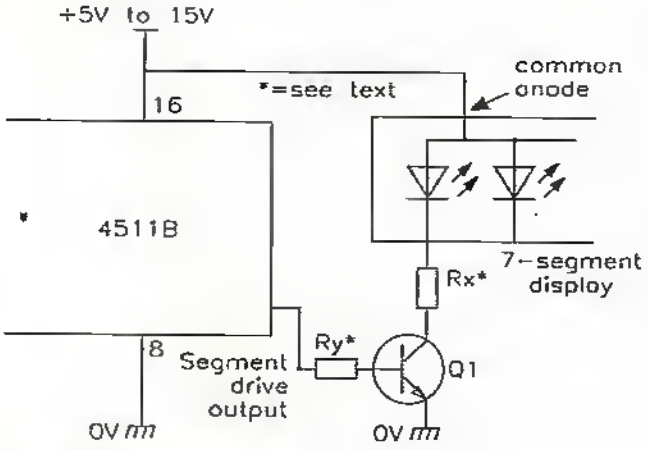


Figure 6. Driving a common-anode LED display.

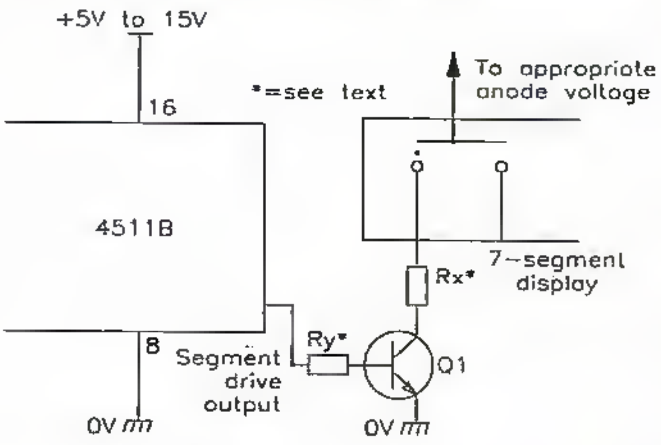


Figure 7. Driving a gas discharge readout.

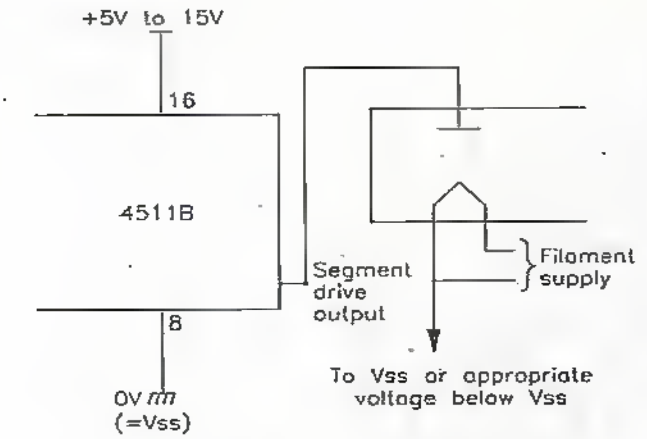


Figure 8. Driving a low-brightness fluorescent readout.

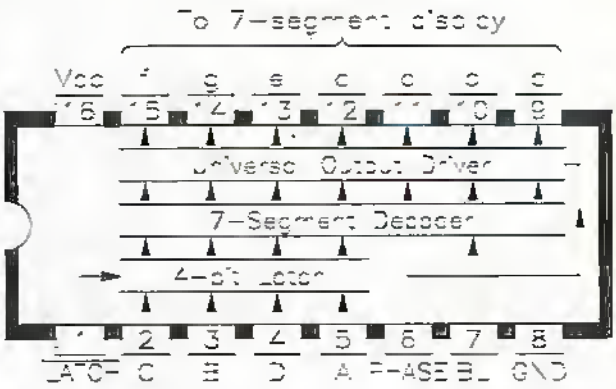


Figure 9. Functional diagram and pin notations of the 4543B universal 7-segment latch/decoder/driver IC.

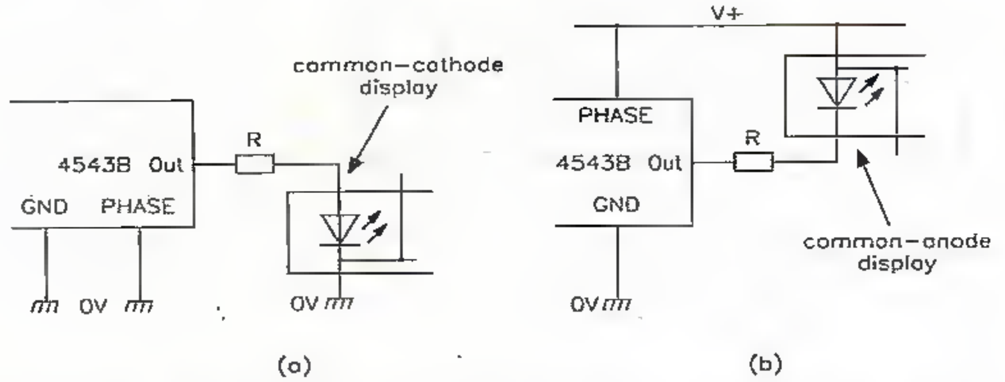


Figure 10. Way of using the 4543B to drive (a) common-cathode or (b) common-anode 7-segment LED displays.

squarewave 'phase' signal and a set of EX-OR gates in a configuration similar to that of last month's Figure 11. In practice, however, it is far better to use a 4543B IC for this particular application.

The 4543B

The most popular 4000B-series BCD-to-7-segment LCD-driving IC is the 4543B (also available as the 74HC4543), which has a built-in data latch. Figure 9 shows the IC's functional diagram and pin notations. The device incorporates an EX-OR array (of the type shown in last month's Figure 11) in its output driver network, which can source or sink several milliamps of output current. This feature enables the IC to act as a universal unit that can drive common-cathode or common-anode LED or liquid-crystal 7-segment displays with equal ease, as shown in Figures 10 to 13.

The 4543B has three input control terminals, these being designated not-LATCH, PHASE, and BL (BLANK). In normal use the not-LATCH terminal is biased high and the BL terminal is tied low. The state of the PHASE terminal depends on the type of display that is being driven. For driving LCD readouts, a squarewave (roughly 50Hz, swinging fully between the GND and Vcc values) must be applied to the PHASE terminal: for driving common-cathode LED displays, PHASE must be grounded; for driving common-anode displays, PHASE must be tied to logic high.

The display can be blanked at any time by driving the BL terminal to the logic-1 level. When the not-LATCH terminal is in its normal high (logic-1) state, BCD inputs are decoded and fed directly to the 7-segment output terminals of the IC. When the not-LATCH terminal is pulled low, the BCD input signals that are present at the moment of transition are latched into memory and fed (in decoded form) to the 7-segment outputs until the not-LATCH pin returns to the high state.

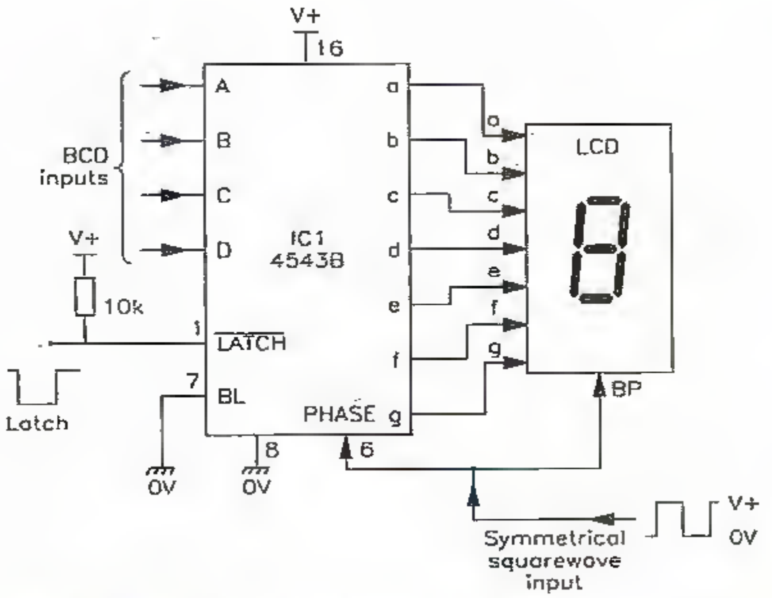


Figure 11. Way of using the 4543B to drive a 7-segment LCD.

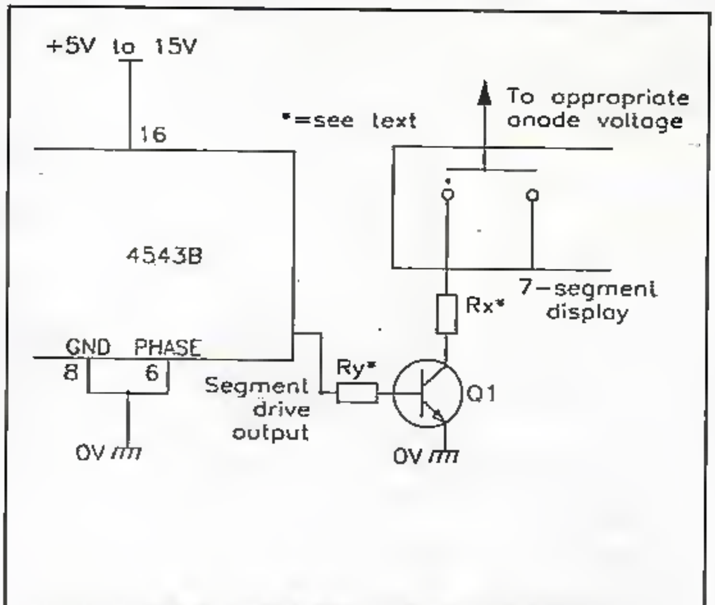


Figure 12. Driving a gas discharge readout with a 4543B.

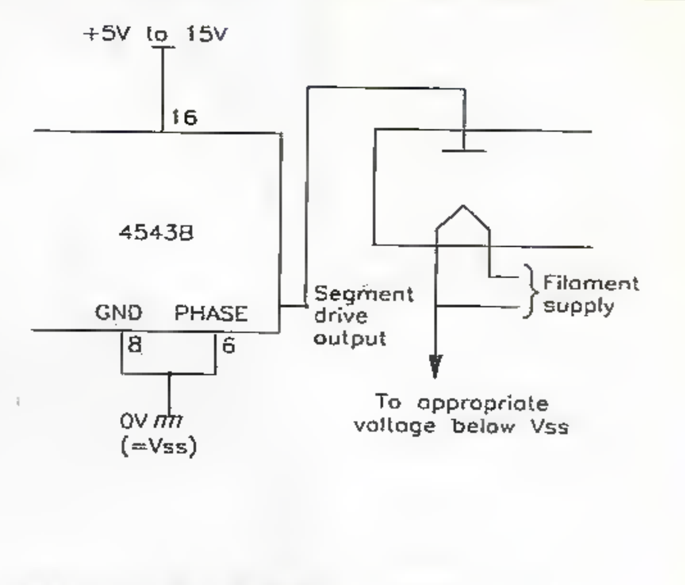


Figure 13. Driving a fluorescent readout with a 4543B.

Figure 10 shows basic ways of using the 4543B to drive common-cathode and common-anode 7-segment LED displays; the 'R' resistance value must limit the output drive current to below 10mA per segment. Figure 11 shows the basic way of using the 4543B to drive a 7-segment LCD, and Figures 12 and 13 show it used to drive other types of 7-segment display; in Figure 12, Rx sets the segment current of the display and Ry sets the base current of the transistor (10mA maximum).

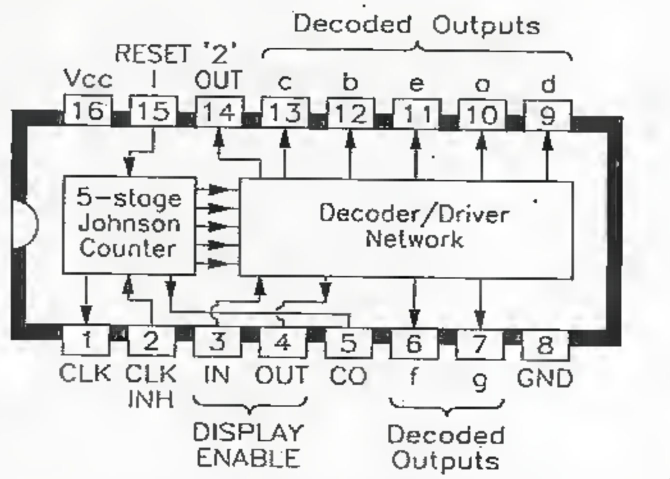


Figure 14. Functional diagram and pin notations of the 4026B decade counter with 7-segment display driver.

The 4026B

The 4026B IC is a complete decade counter with integral decoder/driver circuitry that can directly drive a 7-segment common-cathode LED display. The segment output currents are internally limited to about 5mA at 10V or 10mA at 15V, enabling the display can be connected directly to the outputs of the IC without the use of external current-limiting resistors. The IC does not incorporate a data latch and has no facility for ripple blanking. Figure 14 shows the functional diagram and pin notations of the 4026B.

The 4026B has four input control terminals, and three auxiliary output terminals. The input terminals are designated CLK (CLOCK), CLK INH (CLOCK INHIBIT), RESET, and DISPLAY ENABLE IN. The IC incorporates a Schmitt trigger

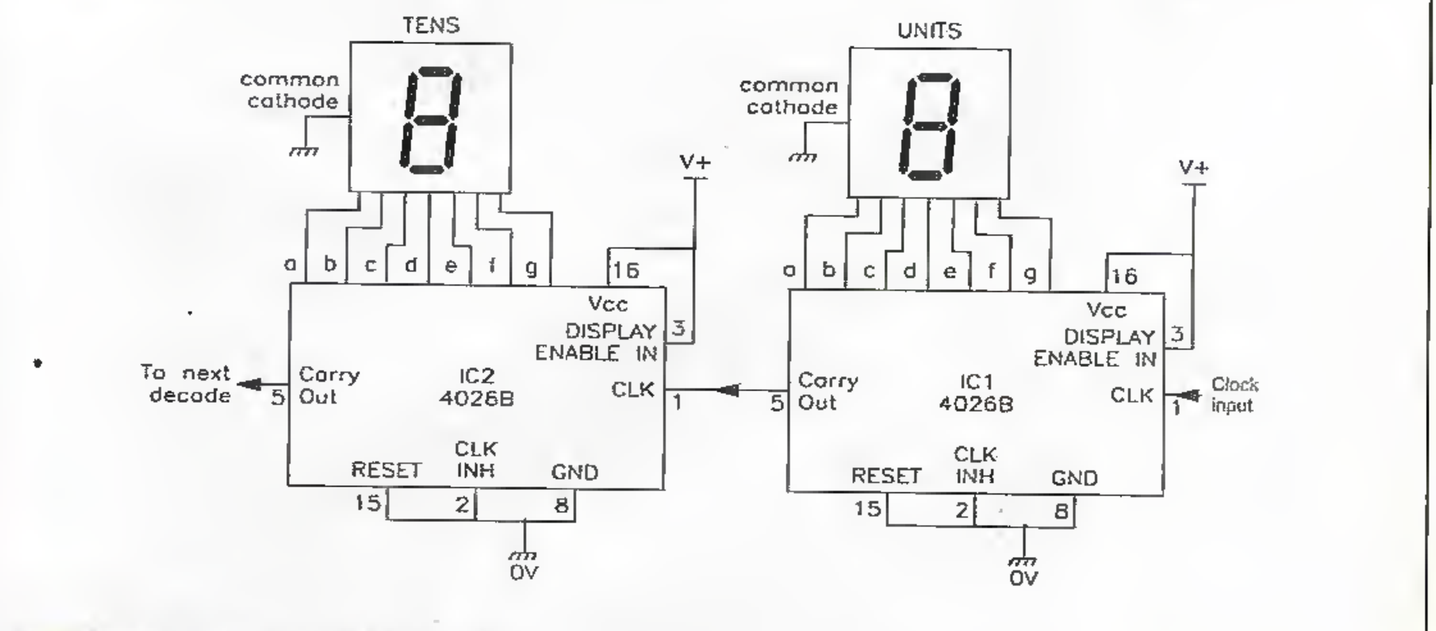


Figure 15. Basic method of cascading 4026B ICs.

on its CLK input line, and clock signals do not have to be pre-shaped. The counter is reset to zero by driving the RESET terminal high.

The CLK INH terminal must be grounded to allow normal counting operation: when CLK INH is high the counters are inhibited. The display is blanked when the DISPLAY ENABLE IN terminal is grounded: the DISPLAY ENABLE IN terminal must be high for normal operation. Thus, in normal operation the RESET and CLK INH terminals are grounded and the DISPLAY ENABLE IN terminal is held positive, as shown in Figure 15.

The three auxiliary output terminals of the 4026B are designated DISPLAY ENABLE OUT, CO (CARRY OUT), and '2' OUT. The DISPLAY ENABLE OUT signal is a slightly delayed copy of the DISPLAY ENABLE IN input signal. The CO signal is a symmetrical square wave at one tenth of the CLK input frequency, and is useful in cascading 4026B counters. The '2' OUT terminal goes low only on a count of 2. Figure 15 shows the basic circuit connections to be used when cascading stages.

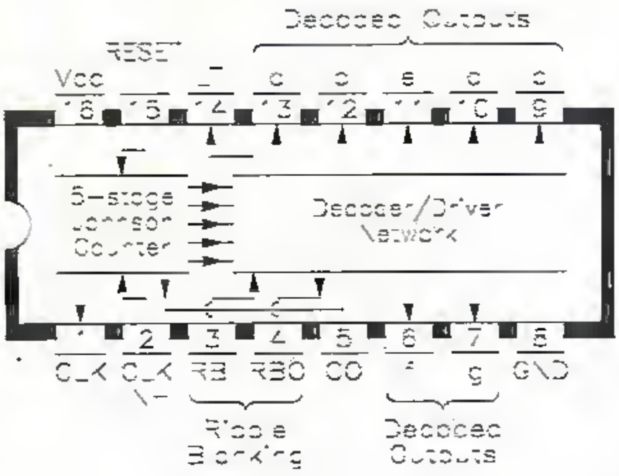


Figure 16. Functional diagram and pin notations of the 4033B decade counter with 7-segment display driver.

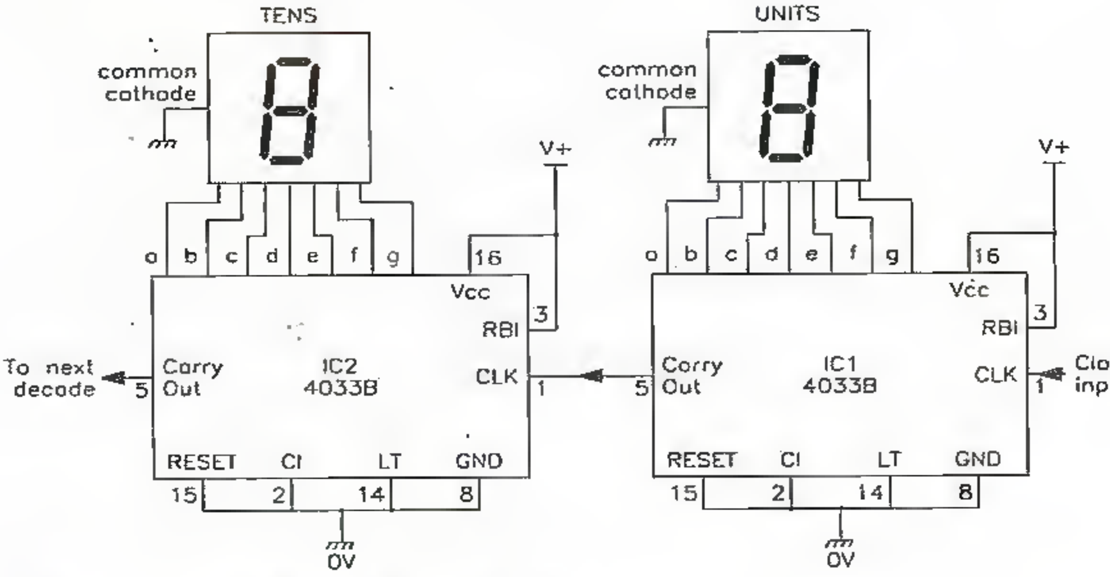


Figure 17. Basic method of cascading 4033B ICs (without zero suppression).

The 4033B

This device (see Figure 16) can be regarded as a modified version of the 4026B, with the DISPLAY ENABLE IN and DISPLAY ENABLE OUT terminals eliminated and replaced by ripple blanking input (RBI) and output (RBO) terminals, and with the '2' OUT terminal replaced with a LT (LAMP TEST) terminal which activates all output segments when biased high. In normal use the RESET, CLK INH and LT terminals are all grounded and the RBI terminal is made positive, as shown in Figure 17: this configuration does not provide blanking of unwanted leading and/or trailing zeros.

If cascaded 4033B ICs are required to give automatic leading-zero suppression the basic Figure 17 circuit must be modified as shown in Figure 18, to provide ripple-blanking operation. Here, the RBI terminal of the most significant digit (MSD) is grounded, and its RBO terminal is connected to the RBI terminal of the next least-significant stage. This procedure is repeated on all except the LSD, which does not require zero suppression. If trailing-zero suppression is required, the direction of ripple-blanking feedback must be reversed, with the RBI terminal of the LSD grounded and its RBO terminal wired to the RBI terminal of the next least-significant stage, and so on.

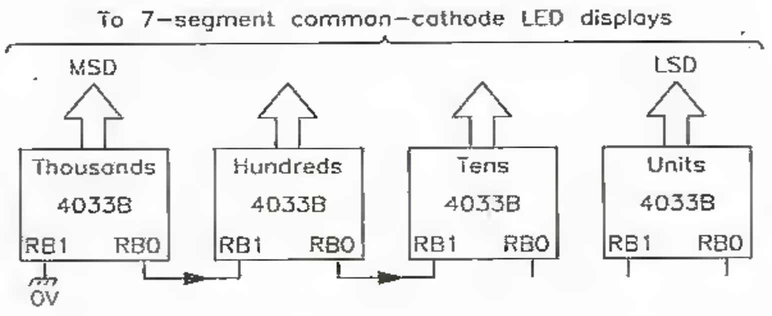


Figure 18. Method of modifying the Figure 17 circuit to give automatic leading-zero suppression.

in the pipeline

ELECTRONICS and Beyond

Don't miss another great assortment of entertaining and easy-to-make projects and essential electronics information aimed at the novice constructor.

Issue 138 will be on sale Friday 7th May

PROJECTS

Metal Detector

Telescope Drive System

IRDA for Printer

Metronome

Water Level Detector

FEATURES

Treasure Hunting

The Science of Scepticism

Remote Control Fixes for Troubled Spacecraft

The Bristol Sound and Vision Show

Project Ratings

Projects presented in this issue are rated on a 1 to 5 for ease or difficulty of construction to help you decide whether it is within your construction capabilities before you undertake the project. The ratings are as follows:

Simple to build and understand and suitable for absolute beginners. Basic of tools required (e.g., soldering, side cutters, pliers, wire strippers, and screwdriver). Test gear not required and no setting-up needed.

Easy to build, but not suitable for absolute beginners. Some test gear (e.g. multimeter) may be required, and may also need setting-up or testing.

Average. Some skill in construction or more extensive setting-up required.

Advanced. Fairly high level of skill in construction; specialised test gear or setting-up may be required.

Complex. High level of skill in construction, specialised test gear may be required. Construction may involve complex wiring. Recommended for skilled constructors only.

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Internet

You can contact Maplin Electronics via e-mail at `<recipient>@maplin.co.uk` or visit the Maplin web site at `http://www.maplin.co.uk`.

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If you get completely stuck with your project and you are unable to get it working, take advantage of the Maplin 'Get You Working' Service. This service is available for all Maplin kits and projects with the exception of: 'Data Files'; projects not built on Maplin ready-etched PCBs; projects built with the majority of components not supplied by Maplin; Circuit Maker ideas; Mini-Circuits or other similar 'building block' and 'application' circuits. To take advantage of the service return the complete kit to: Returns Department, Maplin Electronics PLC., P.O. Box 777, Rayleigh, Essex, SS6 8LU. Enclose a cheque or Postal Order for the servicing cost (£24/hr min +parts) as indicated in the current Maplin Catalogue. If the fault is due to any error on our part, the project will be repaired free of charge. If the fault is due to any error on your part, you will be charged the standard servicing cost, plus parts. A kit building service is on offer for any of our kits. Please contact our customer service department for any pricing details.

COMMENT

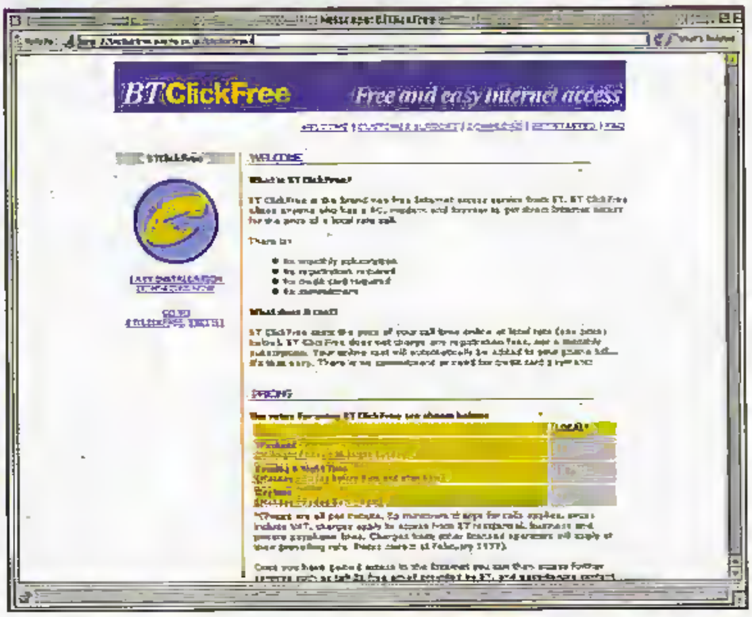
by Keith Brindley

Free lunch, anyone?

While Dixons' Freeserve Internet system was the first mainstream free Internet service (although there were other smaller free Internet services already available), several other major players now appear to be falling over themselves to provide consumers with free Internet access. Dixons already boasts over a million registered users of which around 850,000 of these are active, using the system regularly for email and Web browsing. One of the latest, Tesco the supermarket giant, has recently offered free Internet access to all of its Clubcard loyalty card holders. There are around 10 million Clubcard holders in the UK, so that suggests what sort of market Tesco is hoping to achieve with the free service. Other free services such as the new Cable & Wireless Free4all system, an expected new service from WH Smith, and British Telecom's own repackaged BT Click, are expected to achieve high numbers too - although it's likely that Dixons and Tesco will undoubtedly achieve the lion's share of the potential market, simply because they are higher profile.

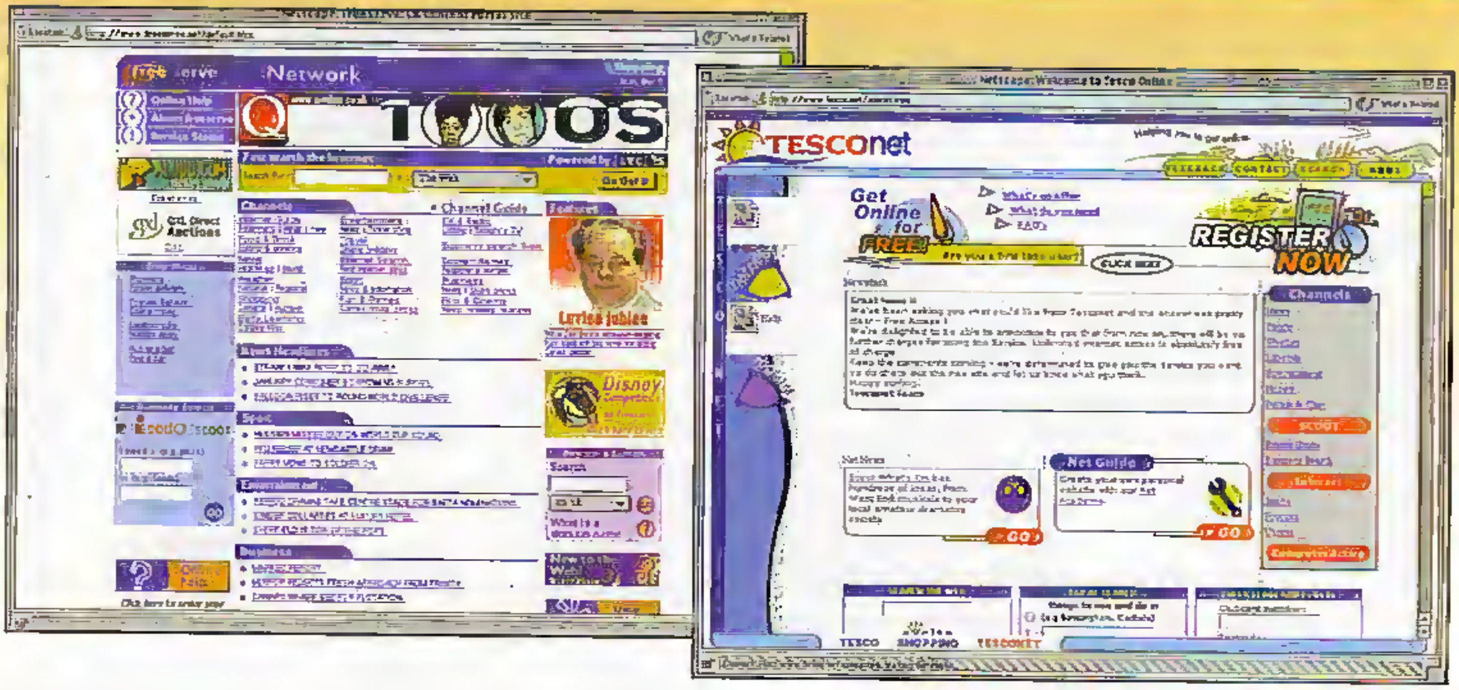
Free Internet services appear to be tremendous value at first sight, but there are hidden snags that potential users should be made aware of. These snags - being hidden - won't have a direct impact on how users take up the services, but they will undoubtedly have an impact on the user numbers the various services will eventually maintain.

First, nobody has a real idea of how many users can initially, or ultimately, be expected. So we'll estimate it, now. In the UK, as elsewhere, the potential market for Internet access has a distinct limit. There are, in total, only 50-odd million people in the UK. Conservatively cutting out half of this number as being too young or too old to require, want, or need Internet access; and halving the number again because it's not expected that all individual family members will have accounts, means that the probable maximum total will be around 12 or 13 million. Given that Internet access via the vast majority of personal computers is not the easiest thing in the world to set up and use yet, it's more likely that a total of 5 or 6 million Internet users throughout the country can be expected to use the Internet regularly in the short-term, rising to the potential maximum of 12 or 13 million in a few years' time. Like the birth of the fax as a general-purpose commercial tool many years ago, nobody has a concrete idea how the future will develop regarding the Internet. Where only a handful of people had a fax machine years back, all but a small handful of businesses, and a large number of ordinary consumers have a fax machine now. The Internet is really only in its infancy at the moment. If we expect Internet users to expand at a similar rate then even this estimate of 12 or 13 million users may be short of the mark. Such high numbers of regular users has a knock-on effect for us all.



For instance, where all these free Internet services leave the traditional paid-for services remains to be seen. Online Internet service providers like AOL, CompuServe, and MSN, together with more traditional Internet service providers like Demon and UUNET, might see an initial fall-off of users as new Internet users jump on the free bandwagon. Also, several existing users might jump ship from a paid-for service to a free one. However, the old adage 'there's no such thing as a free lunch' is probably true when considering free Internet services. At busy times of the day it's often difficult (if not impossible) to get access to the Internet via these free Internet services and, even when connected at other times, the service can be overloaded and quite slow to respond. Also, these ostensibly free services tend to charge premium prices for their accompanying helplines. Given that many, if not most, new users they are encouraging to register are newcomers to the Internet, then there will be many new users who require significant help, at least initially.

Also, while the Internet access these free services provide is free, the actual phone calls users make to logon to the services are ordinary local calls (indeed, this is how the 'free' services make their money, by creaming from BT a percentage of the call price!) which can add up to an effectively hidden 'fee' many times larger than paid-for Internet services' monthly subscriptions. In other words, if you use the Internet



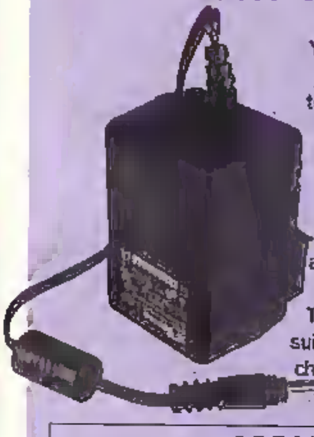
regularly, then the subscription paid to a paid-for Internet service provider is actually only a very small part of your total access costs. Unlike users of free services, however, users of paid-for services enjoy free helplines, and accessibility at all times (even at the busiest parts of the day).

Also, whether or not you think 'free' Internet services are good, just consider the next step along the road. Already in the US there are Internet service providers who provide free computers along with free Internet use, for customers who accept certain terms. Generally, these terms appear to be in one of two ways. First, users have to agree to access the Internet for a specified number of hours each month, provide demographic data for use with targeted advertisers, and have the computers download adverts which will be permanently displayed on the computer screen. Second, users have to buy an agreed amount of advertised products during the contract period.

Up to recent times, the Internet has been rather like a select club. Only the technically competent computer user has been sufficiently capable to become a member, and all members have had to climb up the same learning curve to gain admittance. However, with the advent of new tools to ease the way for new users onto the Internet (Apple's iMac computer, for example) and new Internet systems like these free services which offer a chance to reduce overall cost marginally, there is a new wave of emergent Internet users who are there just for the fun of it.

NEW PRODUCTS • NEW PRODUCTS • NEW PRODUCTS • NEW PRODUCTS

We take a quick look at some interesting new products that are featured in the new Maplin Catalogue



You can now have all the advantages of switched mode power supply technology in a handy mains plug top case. These high power AC/DC adaptors are realistically priced and are available in a wide range of output voltages. Each can be used with a wide range of input voltages and include a short circuit protection system with automatic recovery. These power supplies are particularly suited to the Velleman universal battery chargers featured on page 58 of this issue.

SPECIFICATIONS

Output voltage tolerance:	5%
Input voltage:	90 - 265V AC
Operating temperature:	0°C to 40°C
Ripple/noise (V pk-pk):	1% (20MHz bandwidth)

Order Code	Output Voltage	Output Current	Max. Output Voltage	Price Inc. VAT
PL61R	5V	2A	6.5V	£14.99
PL62S	7.5V	2A	8V	£14.99
PL63T	12V	1.6A	15-17V	£14.99
PL64U	15V	1.3A	17-19V	£14.99
PL65V	18V	1.1A	20-22V	£14.99
PL66W	24V	0.8A	26-29V	£14.99

Antex have introduced a new gas soldering iron, the GasCat (order code RD51F, price £25.49 inc. VAT), a compact pocket sized butane gas (lighter fuel) iron for all those applications where a mains powered one is unsuitable. The strong nylon casing will hold sufficient liquid butane for up to one hours continuous use, and is equivalent to a 70W mains iron. The iron is supplied with a 1mm soldering tip fitted as standard and a protective cap which has an integral flint lighter (good for 900 cycles per flint) and a pocket clip. A range of spare tips are available separately. The maximum torch temperature is 1300°C and the maximum tip temperature is 450°C.

For those meatier jobs the latest self-igniting soldering iron from Antex (order code UD16S, price £34.99 inc. VAT) is ideal, being equivalent to a 120W mains iron. The iron features a piezo ignitor and a maximum torch temperature of 1300°C, and a maximum tip temperature of 500°C. On fill of butane gas (lighter fuel) will last up to one hour. A range of spare tips are available separately.

NEW PRODUCTS • NEW PRODUCTS • NEW PRODUCTS • NEW PRODUCTS

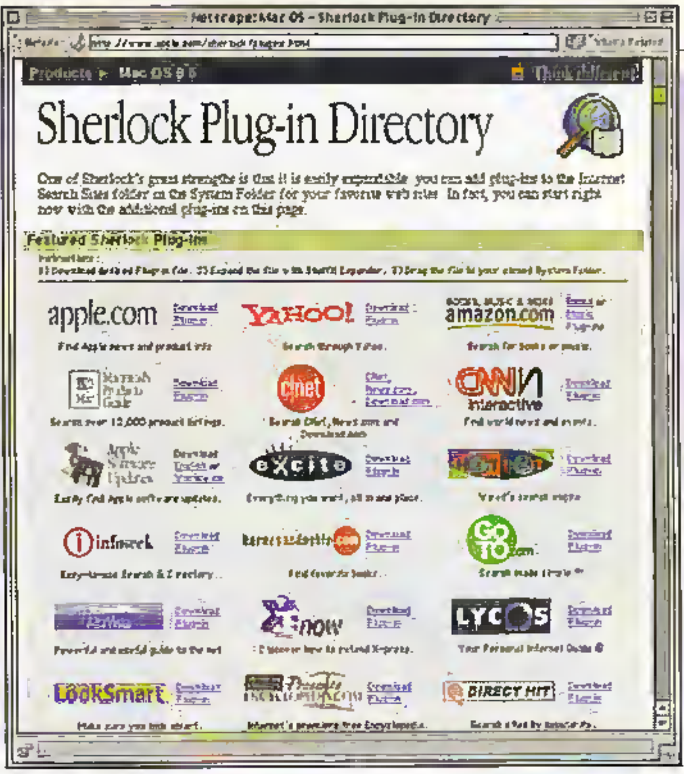
Elementary, My Dear Watson

Last year, the Mac's latest incarnation of operating system - Mac OS 8.5 - was released to unsuspecting Mac users worldwide. This month we are going to highlight one of the unsung heroes of the software, that's now on every new Mac computer (including the iMac) out of the Apple factory. Mac OS 8.5 has actually got several significant benefits over earlier releases and as a result has since been hailed as the best improvement that Macs could hope to have. For a start it is purely PowerPC-native. Unfortunately, this meant that older Macs (that is, those made earlier than about 1995) couldn't use it, so Mac OS 8.1, the previous operating system release, is the latest version that pre-PowerPC Macs could use. But, as a direct result, all the internal code of Mac OS 8.5 is written exclusively for PowerPC Macs, and so runs much faster overall on those personal computers.

Yet Mac OS 8.5 is better too in many other respects, not the least of which is Sherlock. Sherlock is the replacement for the Mac's Find feature (an already useful tool), that extends the Find ability greatly. From within a single tool, users can now search their hard drive for files in all the usual methods, with Finds based on any number of attributes such as name, size, kind, label, date created, date modified, version, comments, lock attribute, and folder attribute. Files on the hard drive can also be found by content, so that users can specify an item of text that they are searching for within files, and Sherlock will find all files with that text in. All pretty powerful stuff, and Sherlock handles them all in an exemplary manner, both speedily and exactly.

But best of all, Mac users can now find things on the Internet too, direct from within Sherlock - without a Web browser open or a search engine in sight (well, not exactly true, because search engines are accessed in the background, as you'll see now). Sherlock works in this way by utilising special search site files, called Sherlock Plug-ins available from search engines. Mac users can download a Sherlock Plug-in from any supporting search engine on the Internet (all important search engines and most others now have Sherlock Plug-ins for Mac users) which allows Sherlock to locate any items accessible by the search engine, directly from within the feature. To use Sherlock to search the Internet, it's simply a question of typing in the item or text phrase, checking the search engine or engines you want to query, and clicking the Search button. Once an item is located you can access it directly from listed hyperlinks, such that if it's a Web URL it can be opened in your Web browser, or if it's an ftp URL it'll be opened in your ftp program. This is an incredibly cool and powerful feature, and you have to use it to believe how useful, speedy, and direct it is. But that's not all, Sherlock automatically checks out its installed Plug-ins while you're using it, and reports back to you if it locates an updated Plug-in, asking you if you want to download it to replace the older version. There's really nothing else quite like Sherlock in existence.

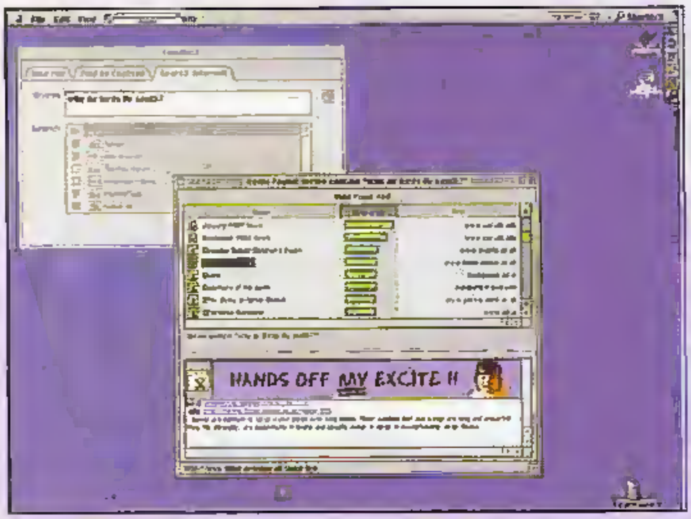
Mac users with Mac OS 8.5 or later on-board should checkout Apple's own listing of the main search engines that support and produce Sherlock Plug-Ins, at <http://www.apple.com/sherlock/plugins.html>, and download them direct from there or from the search engines themselves. Mac users running earlier system software should seriously consider upgrading. Sherlock is worth the cost of the new operating system by itself. The extra speed Mac OS 8.5 gives is just an added bonus.



Sherlock Plug-in Directory

One of Sherlock's great strengths is that it is easily expandable: you can add plug-ins to the Internet Search Sites folder in the System Folder for your favorite web sites. In fact, you can start right now with the additional plug-ins on this page.

Featured Sherlock Plug-ins



AOL And BSkyB Announce Alliance

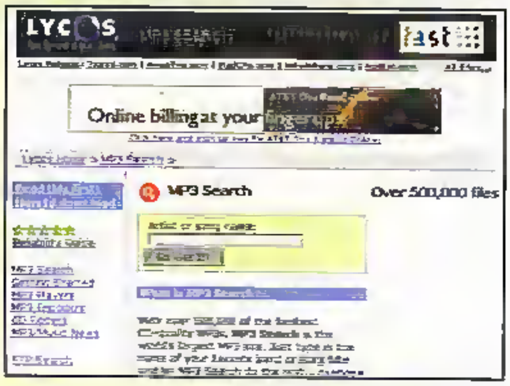
AOL at <www.aol.co.uk> and BSkyB at <www.sky.co.uk> have announced a cross-promotional alliance that will bring the benefits of the two services to a combined subscriber base of nearly 7.5 million.

In a package of measures now being negotiated, BSkyB will be given a significant presence on the AOL service, in exchange for promotion of AOL across the Sky platform, including on Sky's own Web site and consumer guides.

Cross-selling between the two services will provide AOL and BSkyB with an essential subscriber acquisition and retention tool, with new subscribers benefiting from special sign-up offers and promotions to existing members.

As a first move BSkyB will become an anchor tenant on three of the most popular AOL content Channels and will be the premier provider of news on AOL's UK Web site.

Lycos Gets Lyrical



Search engine Lycos is offering a new service that provides links to more than half a million online songs. The new service, called MP3 Search after the MP3 recording technology, is a joint venture with Norwegian firm Fast Search & Transfer, which specialises in image- and video-compression technologies.

From popular music to amateur recordings, MP3 Search gives music fans a quick and easy way to find high quality, low memory MP3 recordings of their favourite songs from one central location. The new MP3 Search site contains searchable Web links to over half a million MP3 files - 10 times larger that any other MP3 file resource. MP3 Search is available at <mp3.lycos.com>, and accessible through the Lycos.com homepage under Advanced Search.

One of the hottest breakthroughs in audio technology, MP3 allows users to quickly download digital recordings of their favourite songs off the Internet and onto their computers or portable MP3 players, typically for free. Surpassing older file formats that are too large and impractical for distributing music over the Web, MP3's compressed file format requires relatively small amounts of memory but sounds comparable to the quality of a compact disc.

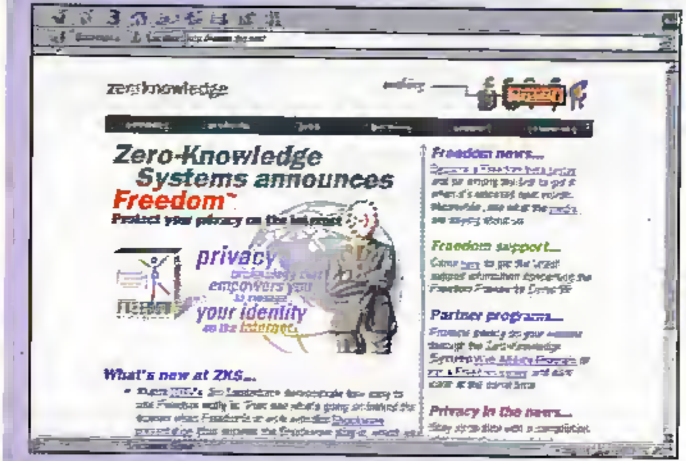
The Internet has become a hotbed for this audio revolution as thousands of Web sites have sprung up offering MP3 files for download. On both the Lycos and HotBot search engines, for example, MP3 is one of the top five searches. Lycos decided to enter this new market after discovering that MPEG was the second most popular search term, beaten only by sex.

Free PC Offer Deluged

A US start-up called **Free-PC.com** at <www.free-pc.com> this month announced plans to offer consumers a free sub-£600 Compaq PC plus Internet access, in exchange for agreeing to use the machine at least 10 hours a month and downloading advertising that is displayed in a strip on the right side of the screen.

Within days of making the announcement Free-PC.com was deluged with 375,000 applications. The company had planned to distribute only 10,000 PCs in the first 90 days, starting with people who fit advertisers' desired demographics. Later on, Free-PC.com hopes to have enough computers to supply less affluent applicants.

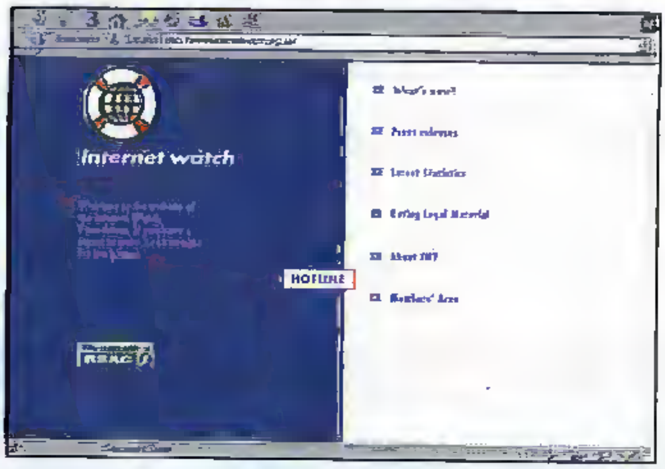
Browser Hides Personal Identity



A Canadian company called Zero Knowledge at <www.zks.net> claims to have a new browser, Freedom 1.0, that guarantees anonymity on the Internet. A 45-day evaluation copy of the new browser will be available from the Zero Knowledge Web site from March.

Speaking to *Electronics and Beyond*, Austin Hill, president of Zero-Knowledge Systems said, "When you browse the Internet, your personal information is routinely collected and often distributed without your knowledge or consent. With Freedom, you can safely browse Internet sites, participate in public discussions, chat and send e-mail".

Report Claims Success For Internet Watch Foundation



The DTI has published a report on the Internet Watch Foundation (IWF) at <www.internetwatch.org.uk> by independent consultants KMPG and Denton Hall. The report is available online at <www.dti.gov.uk/iwfreview>.

The IWF is an industry-led, self-regulatory body, set up in September 1996 after discussions between the Police and Internet Service Providers (ISPs), facilitated by the DTI and the Home Office.

The report commends the success of the IWF since its inception in 1996, and makes recommendations for improvement to keep pace with the rapid developments taking place in the Internet industry.

Findings show a steady increase in the number of reports of potentially illegal material received and processed by the IWF, mainly from outside the UK.

The IWF's structure, hotline operations and relationship with the Internet Industry, Metropolitan Police and National Criminal Intelligence Service were all examined as part of the review. Work on developing rating systems, future activities and funding arrangements were also considered.

Executives Lack Sophistication In Valuing Online Initiatives

Jupiter
www.jup.com
MINDSHARE
client login
MOVE FORWARD
Lead your business forward with MindShare. Jupiter guides strategic decision makers in their online initiatives.
CONSUMER ONLINE
JUPITER NEWS
IN THE STORE

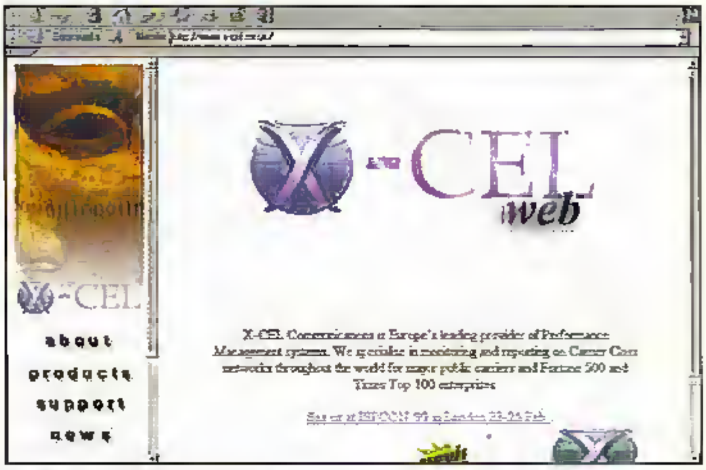
While bosses at 76% of traditional consumer businesses are involved in strategic decision-making for their online initiatives, research from Jupiter Communications at `<www.jupitercommunications.com>` shows that only 24% currently measure the success of their online initiatives as an integrated part of their core businesses.

According to Jupiter, business leaders must integrate the metrics of their Web ventures into those of their traditional businesses in order to measure the Web initiative's true contribution to the overall corporation.

Net-Dependent Students Drive Availability Assurances

Higher education institutes are now able to ensure that their students receive information via the latest range of computer-based data sources. Using network performance management software, colleges can take a long-term, proactive approach to planning IT requirements, enabling them to adopt new services as they become available.

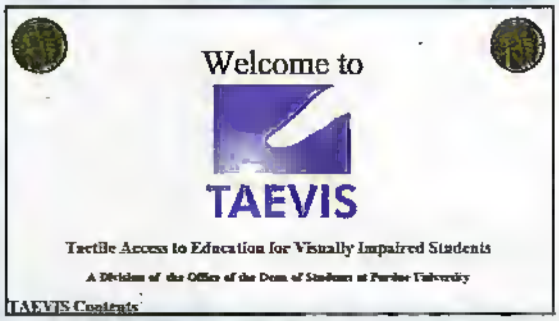
The University of Hertfordshire has just implemented a performance management system at its central campus to analyse trends in network usage and predict system performance. Using Net-Tell software from X-CEL at `<www.x-cel.co.uk>` the University will be able to provide efficient data transmission and server facilities to students located at its distributed sites and colleges throughout Hertfordshire.



X-CEL Communications is Europe's leading provider of Performance Management systems. We specialise in monitoring and reporting on Carrier Class networks throughout the world for major public carriers and Fortune 500 and Times Top 100 enterprises.

Research Programme Aids Visually Impaired

A US University research and development program at `www.purdue.edu/odos/TAEVIS/index.htm>` has created an online application that allows visually impaired students to work with charts, graphs, diagrams, and maps. A drawing printed on special paper is run through a heater that causes the black ink lines, Braille letters and markings to bubble up in a raised image.



Welcome to

TAEVIS

Tactile Access to Education for Visually Impaired Students

A Division of the Office of the Dean of Students at Purdue University

TAEVIS Contents

Service Provider Free For All

In the past month, three of the biggest names in the Internet Service Provider (ISP) market - Tesco, BT and the Virgin Group - have abandoned their monthly payment business model and offering a free service instead.

The move toward free Internet access has been sparked by five-month-old Freeserve operated by retailer Dixons, which has attracted more than 1.3 million users - more than double the number claimed by its nearest competitor, AOL.

New Soldering Website with Tips and Prizes

Antex Electronics, the soldering equipment people who provide accessories for schools and colleges, hobby electronics and product servicing worldwide, has launched a new web site with technical tips, product information and prize competitions. The Antex web site at `www.antex.co.uk` includes features on a wide range of soldering topics, from selecting products and accessories to techniques, problem solving and safety.

The site has its own search engine for easy access to information through drop-down menus or keywords. This is backed-up by a glossary of soldering terms and a Frequently Asked Questions (FAQ) section, dealing with both product and general queries. There is also a comprehensive list, with Internet links, to the network of distributors in the UK, Europe, Americas, Africa, Asia and Australasia, handling Antex products.

To launch the new site, Antex Electronics is offering all visitors the chance to win free, top of the range soldering products and it is planned to run further promotions, in conjunction with Maplin Electronics, through the web site.

The Antex product range includes electric and butane-gas-powered soldering irons, spares and accessories produced to international standards. Sales Manager, Ian Lockhart said "We see the site as an important educational tool as well as a promotional site for our products. As a dialogue builds with our customers, we will be able to add more information to help them produce better quality and safer soldering."

Further information contact: Antex Electronics Limited Tel: 01822 613565

Welcome to the Antex Website.

You will find here full details of our products and the wide range of spares & accessories available. We have also included some advice on soldering techniques and contact details for our distributors around the world.

This information has been gathered during more than fifty years in the soldering business. - I hope that you find it of some value.

Jim Lunt - Managing Director

TI Joins Liquid Audio In Music Venture

what's new

Welcome to Liquid Audio

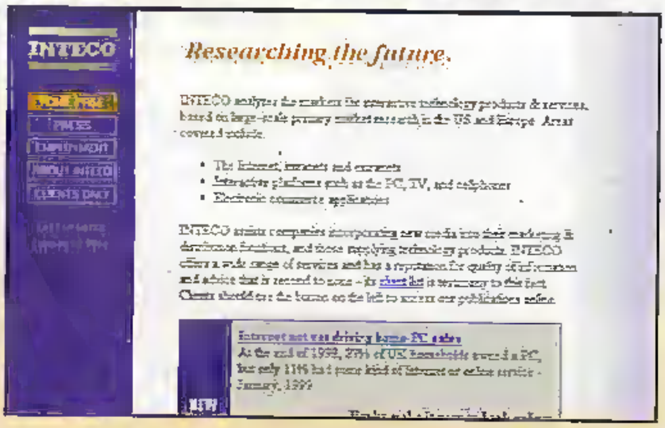
LIQUID AUDIO

Liquid Music Player 4.0 is here!

Texas Instruments at `<www.ti.com>` has teamed up with Liquid Audio at `<www.liquidaudio.com>` to develop technical specifications for a portable music downloading device that would include a copyright protection feature.

The device would be a direct competitor to the Rio PMP300 device, which has raised the hackles of the music industry because it allows the music to be replayed without paying the artist royalties.

Internet Not Yet Driving Home-PC Sales



INTECO

Researching the future.

New research on PC ownership from Inteco at `<www.inteco.com>` shows that, at the end of last year, around a quarter of European households owned a PC, still well behind the US, where penetration is now almost double that level, with the UK leading the three major European markets. The PCs owned are generally powerful - 60% of households purchased their newest system within the last two years and the majority are Pentium-based - yet only a minority are online.

Predictably, recent buyers' systems are more feature-rich than the PCs in the base, for example almost 80% of UK home-PCs are now shipped with a modem. But even among these recent PC buyers, who one might expect to be among the most eager to get online, having the equipment does not necessarily mean using it.

However, Inteco has identified one crucial change, which bodes well for consumer e-commerce in the future. The online activity of early adopters was driven by work-related needs. In contrast, personal use dominates the online activities of recent buyers and this is also now becoming true of the base in general. In fact, overall PC use among recent buyers, particularly in the UK is changing, drifting away from being purely work and education driven to reflect the increasing versatility of the device.

Although increasingly likely to be online and to report the Web as part of their PC experience, recent buyers' Internet usage is still very much a secondary activity. The proportion of buyers citing the Internet as the main reason for their purchase remains small.

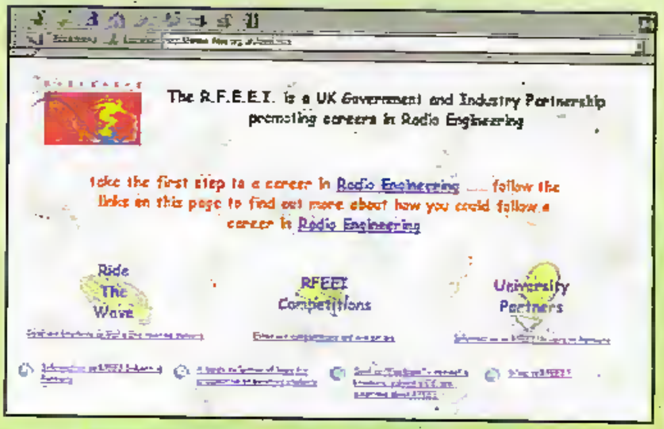
Cyber-Searchlight To Snare E-Trespassers

Unauthorised network entry can now be flagged up in real-time and dealt with immediately, using new intrusion detection software from ISS.

RealSecure is available in the UK from security specialist CenturyCom at `<www.centurycom.co.uk>`. It alerts a central administrator to the location and nature of all network violations as they happen, via messages to the desktop, mobile phone, e-mail or pager. The software then automatically assesses an attack's success or failure, and tracks the trespasser's route across the enterprise.

Illegal intruders coming in through the perimeter defences, or internally accessing areas of the network which are off-limits, can be intercepted or traced. Entry points can then be sealed to prevent any repercussion.

The software forms part of a complete prevention and cure package. This combines real-time intrusion detection capabilities with ISS' vulnerability assessment software, SAFEsuite, which pinpoints security weaknesses and 'back doors' onto the network. By using the two products together, companies can get an in-depth assessment of security policy, as well as real-time updates as to its effectiveness.



The R.F.E.E.I. is a UK Government and Industry Partnership promoting careers in Radio Engineering

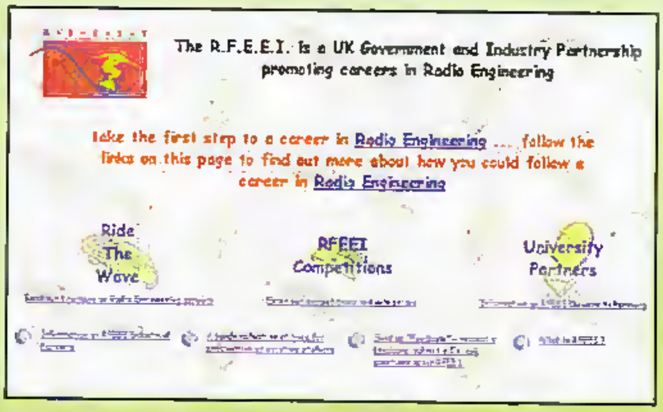
take the first step to a career in Radio Engineering .... follow the links on this page to find out more about how you could follow a career in Radio Engineering

Ride The Radio Wave

Over 20 leading UK companies are throwing their weight behind a Government venture to encourage more students to take up radiocommunications careers and meet the rapidly increasing demand for radio frequency specialists.

The 'Ride the Wave' campaign, welcomed by DTI Telecoms Minister Michael Wills, is the second phase in The Radio Frequency Engineers Education Initiative (RFEEI), an educational venture between Government and the radiocommunications industry.

Spearheaded by the launch of a Web site at `<www.rfeei.org.uk>` to encourage even more students to take up jobs in radio, the campaign offers students the chance to receive information about career opportunities in radio, meet supporting companies in their area, get work experience and even work with industry on their final year projects.



The R.F.E.E.I. is a UK Government and Industry Partnership promoting careers in Radio Engineering

take the first step to a career in Radio Engineering .... follow the links on this page to find out more about how you could follow a career in Radio Engineering

Site Survey

The month's destinations

For all you lovers of old TV progs, check out TV Cream, at <http://www.tv.cream.org>. Here you'll find information about long-dead, archaic, cult, and other obscure programmes. Not only TV programmes, TV Cream houses other media memorabilia too. You can even make suggestions for other links, so if anything you want to see on the site isn't already there, it's in your hands to make it so.

Talking of long-dead, archaic, cult and other obscure things, key <http://www.anglia.ac.uk/~systimk/music/bonzos> into your Web browser, and see a Web site dedicated to the Bonzo Dog Doo-Dah Band. You've probably got to be aged over 40 to know who the Bonzos were, but for the benefit of those readers who are under 40, or who simply blinked too often in the 1960s, they were the archetypal lunatic fringe comedy group. Several big names emerged from members of the Bonzos, including Vivian Stanshall, Neil Innes, Jim Capaldi, and Aynsley Dunbar.

Family historians have a treat in store, at GenealogyLibrary.com, where you can search and locate references to a family name in over 1200 online books, databases, and other family-finding resources. The site, available with a hyperlink from <http://www.familytreemaker.com> is produced by Broderbund Software, whose Family Tree Maker is one of the world's most popular genealogy programs.

On a more mundane level, Bob's Print Guide is a Web site designed to make the problems of professional printing seem a little less of a bind (Yes, it's a pun! Alright?). It's a good stopping off point if you have to interface with professional printers and don't really know the difference between saddle stitch and PostScript. Check out the facts first, then negotiate lower print rates, at <http://www.bobs.co.uk/print/PrintHome.html>.

Finally, it's getting closer, and it's as well we can all laugh about it. The Millennium Bug, otherwise known as Y2K, that is: Duh-2000 is a wonderful site that compiles as many stupid things that have been said about the Year 2000 problem as it possibly can. For example, a quote from US Vice President Al Gore - "How could this be a problem in a country where we have Intel and Microsoft?". Check it out and howl (with both laughter and despair) at <http://www.Duh-2000.com>.

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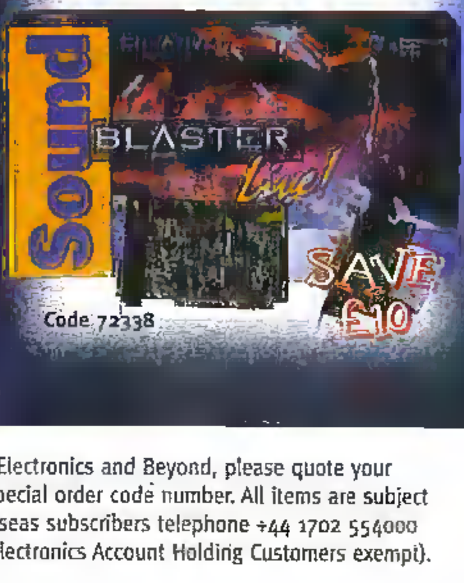

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